LABORATORY EXERCISES

AGRICULTURAL BOTANY

By

SAM F. TRELEASE, PH. D.
Associate Professor of Plant Physiology
College of Agriculture
University of the Philippines

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LOS BAÑOS

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INTRODUCTION

This set of laboratory exercises has been prepared for use with Dr. Copeland's *The First Year of Botany* [1] in an introductory course in agricultural botany. This course is pre-requisite to courses in plant physiology and plant pathology and is fundamental to a study of agronomy.

In the choice of material, plants having direct agricultural usefulness have been selected wherever possible. The aim throughout has been to emphasize the practical utility of the facts and principles learned in the laboratory, and to lead the student to see their applications to plant physiology, plant pathology, and agriculture. The attempt has been made to select material that shows structures that are typical of a large number of crop-plants, rather than those that are of interest because of unusual or abnormal characteristics. In general, the principal crop-plants of the Philippines are made the chief subjects for study. But the plant materials have not been exclusively limited to these plants. In the section on systematic botany, for example, mosses, algae, and ferns, have been included for the sake of developing a coherent knowledge of some of the fundamental principles of plant relationship. To facilitate the use of standard botanical text-books by the student, plants of the temperate zone which are somewhat similar in type to those here studied are indicated by means of footnotes.

The subject matter of these laboratory exercises is presented in as simple a manner as possible. But in spite of this simple method of treatment, it is believed that these exercises are in most cases scientifically accurate and are comparable in the subject matter covered, with most of the elementary courses given in other colleges. The directions and explanations have been treated rather more completely than is common in laboratory manuals. This method has been found to be more satisfactory than that of presenting the material to the class by detailed oral explanations.

Herbarium collections are made by the student throughout the period of the course. For this reason, the student makes a detailed study of the flower at the beginning of the course, in order to obtain a basis for the use of floral characters in the identification of plant collections. [2]

It has seemed advisable to include in this elementary course some simple experiments to illustrate the most important phys-

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[1] Multigraphed by the College of Agriculture, Los Baños, 1919.

[2] In the identification of plants the student is expected to use Prof. Merrill's **A flora of Manila** and Dr. Copeland's **Key to the families of vascular plants in the Philippine Islands.** Bureau of Education, Bulletin 24. 1906.

iological processes of the plant,—such as transpiration, absorption, photosynthesis, respiration, and growth. Some of these experiments may be introduced as demonstration experiments for the whole class, while others may be performed by each student individually.

No claim for originality is made for this work. A large number of books have been consulted in its preparation. And the definitions, explanations, and plans of exercises have been drawn from whatever sources have seemed best. Special mention should here be made of the material taken from Professor Merrill's *A Flora of Manila.* This excellent manual has been used as the basis for the descriptions of plant families. In some cases, these descriptions have been simplified by elimination of technical terms not previously explained to the students.

It is a pleasure to acknowledge indebtedness to Professor Ç. F. Baker, Professor William H. Brown, and Professor F. T. McLean, for suggestions and criticisms; and to Miss Emma S. Yule for aid in the preparation of the manuscript.

Los Baños, P. I., April, 1919.

PART I

PHYSIOLOGICAL PLANT ANATOMY

I. GENERAL EXTERNAL CHARACTERISTICS OF THE PLANT

A. THE PARTS OF THE PLANT

Solanum melongena, Egg Plant, Solanaceae[3]

1. Obtain a whole plant, with roots and flowers and fruit. What is the color of the plant? What is its size?

2. *Root.* What is the direction of growth of the root? The main root, which usually grows directly downward, is called the *primary root.* The branches that come from the primary root are called *secondary* roots; the latter give rise to *tertiary* roots, etc. Do you find particles of soil clinging to the youngest roots? Do you find any leaves on the roots? Do you find joints? Roots have two principal functions: (1) *absorption,* taking in from the soil water containing mineral substances, and (2) *anchorage,* holding the plant in its place. Draw a portion of the root system, showing *primary, secondary,* and *tertiary* roots, and clinging soil particles.

3. *Shoot.* The part of the plant above the ground is the shoot. It is composed of *stem* and *leaves.* The stem is the part which grows upwards. The flat, thin outgrowths of the stem are the *leaves.* The places where leaves are borne are *nodes,* and the parts between the nodes are the *internodes.* Branches of the shoot arise in the angles above the leaves. Branches are composed of stems and leaves. The principal functions of the stem are (1) to expose the leaves to the light, and (2) to carry materials from the root to the leaves and from the leaves to the roots.

Examine a mature leaf. Observe that it consists of (1) a *blade* or *lamina,* which is the thin, flat portion, (2) a stalk or *petiole,* and (3) the base, where the leaf is attached to the stem. In some plants the base has two flattened portions, called *stipules.* Do you find any stipules? The tough threads running through the leaf are called *veins.* The large central vein is the *midrib.* Note that the veins are distributed through the leaf as an irregular network. This leaf is *netted-veined.* Do you find hairs on the leaf? Are the upper and lower surfaces of the leaf alike in appearance? The principal function of the leaf is to change water and carbon dioxide gas into food (sugar and starch).

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[3] Tomato, cotton, beans, tobacco.

Light is used in this change or *process*. The process is called *photosynthesis* (meaning a putting together under the influence of light). Draw a leaf, and label all its parts.

4. Examine the *flowers*. The function of flowers is to produce *fruits* containing *seeds*. In what position are the flowers borne? Flowers are composed of modified leaves, *floral leaves,* and the modified tip of the stem that bears these floral leaves. Draw the flower and the stem on which it is borne.

5. Examine a fruit. This is formed from a part of the flower. The fruit contains *seeds,* whose function is to reproduce the plant. Draw a fruit.

6. Examine your plant for *buds*. Buds are undeveloped shoots; some *buds* develop into stems bearing ordinary green leaves; other buds develop into flowers.

B. THE FLOWER

Solanum melongena, Egg Plant, Solanaceae[4]

The flower is the part of the plant whose work is to produce seeds. The seeds have the function of producing new plants. Note that at the outside there is green structure; this is called the *calyx*. The function of the calyx is protective. Above the calyx observe the bluish colored part. This is the *corolla*. Inside the corolla is a group of parts called the *stamens*. These produce a yellow powder called *pollen*. In the very center of the flower is a structure called the *pistil*.

Remove the calyx and corolla, and examine the pistil. With a knife make a transverse cut through the lower enlarged part of the pistil. This enlarged, hollow part of the pistil is the *ovary*. Note the small, round structures, called *ovules*. These are the bodies which develop into seeds. Examine the specimen with a hand lens. Into how many *cells* or compartments is the ovary divided? How are the ovules distributed in the ovary? Each ovule is attached by a small stalk, called the *funiculus* (from *funis,* a rope). The middle part of the ovary, where the walls of the cells meet, is the *axis*. The part of the ovary which bears the ovules is called the *placenta;* and the arrangement or mode of attachment of the placentae is called the *placentation*. If the ovules are attached to the axis of the ovary, the placentation is *axillary*. If the ovules are attached to the walls of the ovary, the placentation is *parietal* (from *paries,* a house wall). In this flower is the placentation *axillary* or *parietal?*

Examine the end of the pistil from another flower. The part of the pistil which receives the pollen grains is the *stigma*. Is the surface of the stigma rough or sticky? The stalk bearing the stigma is the *style* (from *stylus,* a column). Make a drawing (8 cms. long) of the pistil, showing stigma, style, and ovary.

[4] See preceding footnote.

Draw a side view of the ovary cut vertically to show the ovules (8 cms. long). Draw the end view of an ovary cut transversely to show the placentation and the number of cells.

The Pollen. Examine the stamens which surround the pistil. Examine a stamen that is shedding the *pollen* grains. The stalk of the stamen is the *filament,* and the upper, enlarged part is the *anther.* The anther contains the *pollen sacs,* filled with pollen. Where do the pollen sacs open to discharge their contents? The mode of opening of the pollen sacs to discharge the pollen is called *dehiscence.* Draw (8 cms. long) a stamen, showing the filament and the anther. Draw (3 cms. long) a side view of an anther, showing dehiscence.

The pistil and stamens are called the *essential parts* of the flower, because they are the parts necessary for the formation of seeds. Seeds are formed from ovules by a complex process following the transfer of pollen grains from the stamens to the pistil (*pollination*). Some flowers contain only these essential parts (pistil and stamens); but most flowers contain other parts which form the *perianth.* The outer, green and leaf-like cup of the flower is the *calyx;* the inner set of flower leaves is the *corolla.* Calyx and corolla together form the perianth.

The perianth. Note the *calyx* and *corolla* which surround the pistil and the stamens. Do the calyx and corolla differ in color or appearance? Hold the corolla up to the light. Does it contain veins like those of ordinary green leaves? The calyx is composed of modified leaves or *sepals.* The sepals may be separate and free, or they may be united to form a tubular structure. Similarly the *corolla,* or the inner part of the perianth, is composed of modified leaves called *petals.* The petals may be free or they may be united. The divisions in a calyx or corolla composed of united parts are called *lobes.* Draw the calyx and the corolla.

The relative positions of the parts of the flower. a. Cut a fresh flower in halves lengthwise. Draw (8 cms. long) the cut flower as seen from the cut side. Show where all of the parts of the flower are attached. If the perianth is attached below the ovary, it is *hypogynous,* and the ovary is *superior.* If the perianth is grown fast to the whole length of the ovary, it is *epigynous,* and the ovary is *inferior.* The end of the stem which supports the perianth, stamens, and pistil is called the *receptacle.*

b. Look down into the end of the flower. Determine the relative positions of calyx lobes, corolla lobes and stamens. Also determine the relation of the cells of the ovary to these parts. Make a diagram of the flower (*floral diagram*). In this diagram show a transverse section of the ovary. And in a circle around the ovary make small circles to represent the positions of the

stamens. Show the position of the corolla lobes by arcs of a circle. Since these arcs represent petals which are united, connect the arcs by dotted lines. Around the arcs which represent the corolla lobes draw similar arcs to represent the calyx lobes. Are the calyx lobes to be placed on the same radii as the corolla lobes, or on alternate radii? Since the stamens are joined to the corolla, connect the circles representing stamens with the arcs representing corolla lobes.

C. THE FRUIT

Solanum melongena, Egg Plant, Solanaceae [5]

1. Examine the fruit of the Egg Plant. The fruit is the structure which contains one or more seeds. The fruit is developed from the ovary as the result of a complex process, called *fertilization,* following pollination. Is this fruit fleshy or dry? Is this fruit covered by a stony, hard case? A soft, fleshy fruit is called a *berry.* Is the papaya fruit a berry? Give other examples of berries. What parts of the flower do you find represented in the fruit? Which of the following parts do you find: calyx, corolla, stamens, stigmas, style, ovary? Make a drawing (8 cms. long) showing the whole fruit.

2. Then cut the fruit lengthwise. Observe the seeds. Make a drawing showing the distribution of the seeds. The seeds are structures which reproduce the plant. They are developed from ovules, as a result of *fertilization.* Make a drawing (1 cm. long) of a single seed.

D. PARTS OF A MONOCOTYLEDON [6]

Oryza sativa, Rice, Gramineae [7]

Obtain a rice plant with roots and flowers or seed. This plant belongs to the *Gramineae* or grass family. Examine the plant as a whole. How does it differ in general appearance from the Egg Plant? Make a drawing to show its general habit of growth. Compare the *root system,* as to size and manner of branching, with the root system of Egg Plant. Are there any *soil* particles clinging to the roots? The roots of rice, like those of other grasses, are described as *fibrous.* What are the two principal functions of the roots? Draw a portion of the root system.

The *shoot,* you remember, is composed of *stem* and *leaves.* Where do branch stems arise? Is the stem hollow, or solid? The characteristic hollow stem of a grass is called a *haulm,* or *culm.* Examine a leaf. It consists of (1) a *sheath,* the part

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[5] See preceding footnote.

[6] Plants which produce seeds in an ovary are classified in two large groups, Monocotyledones and Dicotyledones.

[7] Wheat, oats, corn, sorghum, barley, rye.

that surrounds the stem, (2) a *blade,* the flat expanded portion, and (3) a *ligule,* the thin membrane at the place of union of blade and sheath. Frequently the leaf also bears two short, curved outgrowths called *auricles* (auricle, ear-lap). These are situated at either side of the ligule, and are often brown and covered with hairs. How many large veins has the leaf? Are they all equally large? What is the direction of the veins? Such a leaf is called *parallel-veined.* How does the venation of this leaf differ from that of the Egg-Plant? Note that the uppermost leaf has not yet expanded. Draw a mature leaf.

Observe the cluster of flowers or fruits. The flowers are borne in an irregularly branched flower cluster called a *panicle* (*panicula,* a tuft). The single *inflorescences* are called *spikelets.* Draw a portion of the panicle, including about twelve spikelets.

II. THE SEED

The *seed* is a reproductive structure which develops from an ovule as a result of fertilization, and contains a young plant, the *embryo,* in a resting condition. The seed contains food material, either in the embryo itself or in tissue outside the embryo. The embryo and food reserve are protected by *seedcoats.* The seeds, or the fruits containing the seeds, are capable of being distributed, this process being called *seed dispersal* or *dissemination;* thus as seeds plants are transported away from the parent plants. Under suitable conditions of moisture, temperature, and air supply, the embryo renews its growth; this is called the *sprouting* or *germination* of the seed. The young plant, or the *seedling,* produced by the germination of the seed, uses in its early growth the food which has accumulated in the seed. The function of seeds is to produce new plants.

A. THE SEED OF LIMA BEAN

Phaseolus lunatus, Patani or Lima Bean, Leguminosae

1. External Structure of the Seed.

Examine a pod containing bean seeds. Open a pod and find where the seeds are attached. The *cord* which connects the ovule or seed to the placenta is called the *funiculus* (from *funis,* a rope). Tear a bean from its attachment. The mark left on the seed at the point of attachment to the funiculus is the *hilum.* Locate a minute opening at one end of the *hilum.* This opening is called the *micropyle* (from a word meaning a small gate). What was the function of the micropyle in the ovule? What might be a function of the micropyle in the seed? Draw (4 cms. long) a side view of the bean seed. Make another drawing to show the hilum and micropyle.

2. Internal Structure of the Seed.

Remove the outer seed coat, *testa,* of a soaked bean. Try to find an inner coat, *tegmen,* under it. What is the function of the seed coats? The thick white structures beneath the seed coats are the *cotyledons* or first leaves of the young plant. How many cotyledons do you find? Look for several very small leaves between the cotyledons. These are a part of the *plumule* (from *plumula,* a little feather). The plumule is a bud which develops into the first typical leaves and the upper part of the stem of the plant. The cylindrical structure attached to the plumule is the *hypocotyl* (meaning below the cotyledons). The hypocotyl

develops into the lower part of the stem and into the root. The *embryo* is the young plant formed in the seed. The cotyledons, plumule, and hypocotyl are parts of the embryo, while the seed coats are not. Draw (4 cms. long) the embryo with one cotyledon removed, showing the plumule, hypocotyl, and a cotyledon.

3. Food Supply of the Embryo.

Crush a small portion of the cotyledon of the bean and add a few drops of iodine solution. What color change do you observe? Starch is white and is stained blue by iodine solution. What kind of food is stored in the cotyledon? Most of the food to be used in the growth of the young plant is stored as starch in the cotyledons.

B. THE SEED OF MAIZE

Zea mays, Maize, Gramineae

Examine a grain of maize and note that one flattened side appears lighter in color than the other. The embryo is situated under this lighter portion. Next examine a grain that has been soaked in water and has swollen. Examine the skin that covers it. This covering is composed of the wall of the ovary adhering to the seed coat within.

Cut the seed lengthwise with a razor, and examine with the hand lens. Observe the embryo, with the *plumule* pointed toward the large end of the seed, and the *radicle* (from *radiculus,* a small root) at the small end of the seed. The plumule consists of several leaves and the growing point that will develop into the stem. The part of the seed to which the plumule and radicle are attached is the *single cotyledon.* Its function is to absorb food from the rest of the seed for the embryo.

The rest of the seed is the food material called the *endosperm* (meaning within the seed). The endosperm is formed in the ovule, but is not a part of the embryo. Test the endosperm with iodine solution. Does it turn blue? Does it contain starch? The cotyledon lies in contact with the endosperm and absorbs the food stored in the endosperm. Make a drawing (6 cms. long), of the cut surface and label all of the parts of the grain. How does the bean seed differ from the corn grain in number of cotyledons? Plants having one cotyledon are called *Monocotyledones.* Rice and coconut are examples of *Monocotyledones.* Plants having two cotyledons are *Dicotyledones.* Calabaza, peanuts, and castor beans are examples of Dicotyledones. Do the bean seed and corn seed have the same kind of food stored? How does the bean seed differ from the corn seed in the place of food storage? This is not a constant difference between Monocotyledones and Dicotyledones; most Monocotyledones have food storage in the *endosperm,* but many Dicotyledones also have food storage in the *endosperm.*

C. THE SEED OF COCONUT

Cocos nucifera, Coconut, Palmae

The outer fibrous husk and the inner hard shell are parts of the fruit of the coconut. Remove the fibrous husk. Examine the *three* eyes at one end of the hard shell. The embryo lies under one of these eyes. Split or saw the nut through the eyes. The thick, white *meat* of the coconut is the *endosperm;* the liquid is also a part of the endosperm. The endosperm, when dried, is *copra.* Find the embryo. Examine the *radicle,* the end next to the shell. The other end of the embryo is the single cotyledon. The plumule is embedded in the cotyledon. Make a drawing (8 cms. long) to show the parts of the seed.

D. THE SEED OF CASTOR BEAN

Ricinus communis, Tangan-tangan or Castor Bean, Euphorbiaceae

Cut off the hard outer seed coat from the small end of the seed and then run the point of the knife around the edge of the seed to separate the two halves. Examine the inner structure with a hand lens. Find the embryo. The thin, colorless leaves are the cotyledons. The cylindrical structure below the cotyledons is composed of hypocotyl and *radicle.* The material which surrounds the embryo is the *endosperm.* Make a drawing (5 cms. long) of the seed with one-half of the endosperm removed. Make another drawing of the complete embryo, removed from the endosperm. Where is food stored in the castor bean seed? Crush a piece of the endosperm between your fingers; note the oily feeling. Rub a little on a piece of thin paper. Does the spot allow the light to pass through it? What sort of food is stored in this seed? Compare as to structure and function the cotyledons of castor bean with those of the bean seed.

E. THE STORAGE OF FOOD USED IN THE GROWTH OF THE SEEDLING

Qualitative Tests for Foods

a. *Starch.* Test with dilute iodine solution. A dark blue color indicates the presence of starch. Grind some of the tissue and strain through a piece of cheese cloth. Boil in a test tube some of the liquid coming through the cloth. The starch in it partially dissolves. Allow it to cool, and add a drop of iodine solution.

b. *Cellulose.* Test with iodine; pure cellulose gives no color change. Test with sulphuric acid and iodine, and note the blue color. Wood, cotton, and paper are mainly composed of cellulose.

c. *Oil.* Rub a little on a piece of thin paper. Oil makes a translucent spot. Squeeze some between your fingers; note the *oily feeling.* Stain with alkanin or Sudan III solution; oil stains an orange-red.

d. *Protein.* (1) In a test tube heat some of the material in concentrated nitric acid. Observe the color. Cool and add strong ammonia; note the orange color. (2) Prepare Millon's reagent by dissolving some mercury in twice its weight of nitric acid (sp. gr. 1.42), performing this operation under the *hood.* When dissolved, dilute the solution with twice its volume of water. In a test-tube place some of the material to be tested. Add a few drops of Millon's reagent and warm. A brick-red color shows the presence of proteins. The *living substance* of plants and animals is mainly composed of proteins; meat and white of egg are rich in proteins.

Examine under the low and high powers of the microscope a cross-section of a grain of rice (*Oryza sativa*). Note the coat which covers the grain. Within this observe the aleurone or protein layer. Within this, is the bulk of the seed which is composed of cells containing stored starch grains. Your section may have been cut in such a way as to include the embryo also. The aleurone or protein layer is especially important as a food. Polished rice has this valuable food removed in the *bran.* Too exclusive a diet of polished rice is believed to cause the disease called Beri-Beri. Rice which has been cleaned in such a way as not to remove this aleurone layer makes a much more nutritious food than polished rice. Make a diagrammatic drawing showing coat, aleurone layer, and starchy region.

After making the necessary tests, complete the following table:

Name of seed.[a]	*Place of food storage.*	*Kind of food stored.*	*Proof.*
Castor bean ..	....	....	....
Corn grain ...	....	....	....
Bean seed	....	....	....
Areca seed ...	....	....	....
Coconut	....	....	....
Rice	....	....	....
Peanut	....	....	....

[a] Wheat, oats, barley, rye, sweet corn, and date.

F. GERMINATION OF SEEDS AND GROWTH OF SEEDLINGS

Obtain seeds of the bean, pea, corn, castor bean, and onion. Soak the seeds for five hours in water and germinate them in moist sawdust. Remove specimens, each day, so as to obtain a complete series from the time the seeds sprout to the time when the first true leaves appear. In addition, study the germination of *Cocos nucifera,* Coconut.

Observe the stages of germination of each seed, and record your observations in a table in which the vertical columns are as

follows:—(1) Part of embryo that breaks through seed coats first; (2) Parts of seed left underground; (3) Part that first appears above ground; (4) Means of protecting plumule; (5) Changes in hypocotyl; (6) Changes in cotyledons; (7) Changes in plumule.

Make a series of five drawings of each kind of seedling to show successive stages in germination, indicating by a horizontal line the level of the sawdust.

G. FUNCTIONS OF COTYLEDONS

In this exercise on the germination of seeds, pay particular attention to the *functions* of the *cotyledons.* Note the following six combinations of functions:—

a. *Pisum sativum,* Pea, Leguminosae. Storage of food; small amount of growth needed to push the radicle (root) and plumule out of the seed.

b. *Phaseolus lunatus,* Lima bean, Leguminosae. *Cucurbita maxima,* Calabaza, Cucurbitaceae. Storage of food; growth needed to push the radicle and plumule out of the seed; manufacture of food (by photosynthesis) after the growth of the hypocotyl has carried them upward into the air.

c. *Zea mays,* Corn, and *Oryza sativa,* Rice, Gramineae. Other grasses. Absorption of food store from endosperm.

d. *Cocos nucifera,* Coconut, Palmae. Absorption of food from endosperm through tip of cotyledon; growth in length of the rest of the cotyledon, pushing the rest of the embryo out of the seed; growth of outside part of the cotyledon determining position of plumule and radicle.

e. *Ricinus communis,* Castor Bean, Enphorbiaceae. Absorption of food stored in the endosperm; subsequent expansion and manufacture of food (by photosynthesis).

f. *Allium sepa,* Onion, Liliaceae. Absorption of food stored in the endosperm by tip; growth in length of the rest of the cotyledon, pushing the rest of the embryo out of the seed; growth of the outside part of the cotyledon, forcing the root into the soil; growth of cotyledon upward, out of the ground, and manufacture of food (by photosynthesis) by it.

III. THE PLANT CELL

A. STRUCTURE OF THE CELL

Cucurbita maxima, Calabaza, Cucurbitaceae

With a knife scrape some of the hairs, *trichomes,* from the tip of the stem of *Cucurbita maxima,* Calabaza (Squash), Cucurbitaceae. Place these in a drop of pure water on a slide; put on a cover glass, and examine first with the low power and then with the high power of the microscope.

Observe that each trichome is made up of several small compartments filled with a translucent substance. These are *cells.*[1] Each cell consists of the walls and contents of a single compartment. The colorless membrane of each cell is the *cell wall.* Within the cell wall note the denser, granular portions composed of the living substance called *protoplàsm,*[2] and the clear spaces called the *vacuoles.* Examine the *cell wall* under the high power of the microscope. The cell wall is not living, but is an elastic supporting membrane around the living cell contents. It is composed mainly of a hard, colorless substance called *cellulose.* Pure cellulose allows water to pass through it easily, and the walls of most cells within the plant allow water to pass through them. But the walls exposed to the air are modified chemically, so that they retard the passage of water through them.

Within the cell wall note the translucent material that appears grayish in color and contains many small granules. This is the living *protoplasm.* It lines the cell wall and forms strands across the central portion of the cell. The protoplasm in a single cell is called a *protoplast.* Every living cell contains protoplasm. The protoplasm has a consistency resembling that of the raw white of an egg or of a thin jelly. Note that the more fluid parts of the protoplasm are moving in slow currents in various directions. This more fluid portion of the protoplasm is the *cytoplasm.* Look for the darker, denser part of the protoplasm near the center of the cell. This is the *nucleus.* It is nearly spherical in shape and is surrounded by the cytoplasm. Each living cell has a nucleus, which appears to control the physiological functions of the rest of the protoplasm.

Look now for the *vacuoles,* which may be recognized as clear spaces surrounded by cytoplasm. The vacuoles contain water and various substances in solution. The clear, watery solution in the vacuoles is called cell *sap.* The sap in the vacuole is not living material, but is composed largely of water. Water enters

[1] Cell; from **L. cella,** a small room.

[2] Protoplasm; from ML **protoplasma,** the first creature made; from Gr. protos, first; **plasma,** anything formed.

the vacuole until the sap presses against the protoplast and cell wall, thus making the cell rigid or firm. This state of rigidity caused by the pressure of the sap against the protoplast and cell wall is called *turgor.* Cells which possess turgor are said to be *turgid,* while those which are not swollen in this way are said to be *flaccid.*

Draw a single cell from the calabaza trichome, making your drawing 10 centimeters long. Indicate by arrows the directions of the protoplasmic streaming.

B. PLASMOLYSIS OF THE CELL

1. Replace the water surrounding the calabaza trichome with a five per cent solution of table salt (Sodium chloride), by the method shown by the instructor. Observe the changes that take place in the cell. Water is withdrawn from the vacuoles by the salt solution. Thus the volume of the cell sap in the vacuoles is diminished. Observe that the protoplasm contracts and no longer presses against the cell wall. This contraction or shrinkage of the protoplasm in a living cell, due to the loss of water, is called *plasmolysis.* The protoplasm withdraws from contact with the cell wall. The cell no longer possesses *turgor.* Before the protoplasm visibly shrinks, the elastic cell wall contracts. Make a drawing (5 cms. long) of a plasmolyzed cell.

Replace the salt solution with pure water. Observe that the cell regains its turgor, due to absorption of water, and appears as it did before plasmolysis.

2. Repeat this experiment, using the cells from the lower epidermis of *Rhoeo discolor* or *Zebrina pendula.* On dry, sunny days plants may often be observed whose leaves and stem tips wilt and bend downward. Under such conditions, the cells of these organs have lost their turgor, because the plants are not able to absorb water from the soil as rapidly as water is being evaporated from the leaves.

C. PERMEABILITY OF THE PROTOPLASM

Experiment to demonstrate that death of the protoplasm increases its *permeability* and allows substances dissolved in the cell sap to escape.

1. *Equipment.* Leaf of *Rhoeo discolor;* slide; cover glass; ether; microscope.

Method: Mount a small strip of colored epidermis of *Rhoeo discolor* in water on a slide; put on a cover glass; and observe under the microscope. Note that the cell sap contains a red stain which does not escape into the water surrounding the cells; the living protoplasm is almost *impermeable* to substances dissolved in the cell sap. Then draw a water-solution of *ether* under the cover glass and note the result. Discuss the results of this experiment.

2. *Equipment.* Root of red beet, *Beta vulgaris;* water; two test tubes, 1.5 cms. in diameter; alcohol lamp for heating water.

Method: Cut two cubes (1 x 1 x 1 cm.) of the root of the red beet, *Beta vulgaris.* Wash both cubes in water and then place each in a test tube filled one-third full of water. Heat the water in one test tube to the boiling point, thus killing the protoplasm of the beet cells. Note whether or not the coloring matter escapes from both cubes. What conclusions may be drawn from this experiment?

D. CHLOROPLASTS

1. Mount a thin cross section of the leaf of gabi, *Colocasia esculentum,* [3] in a drop of water, put on a cover glass, and observe under the high power of the microscope. Note that cells in the interior of the leaf contain small round bodies lying in the protoplasm. These bodies are *chloroplasts.* [4] They are colored green by a substance called *chlorophyll,* [5] which is developed only in parts of the plant exposed to light. Chloroplasts give plants their green color. The chlorophyll enables the plant to manufacture *carbohydrate* [6] food, such as sugar and starch. The process of food manufacture is called *photosynthesis,* [7] because it is a process of combining substances by means of the energy of light. In this process, food is formed from carbon dioxide gas, taken from the air, combining with water, absorbed by the roots. Oxygen gas is given off as a by-product. Photosynthesis is the principal function of all green tissues. It takes place only in the light. Because chloroplasts have definite functions, they are sometimes called *organs* of the cell. Make a drawing (8 cms. high) of a cell containing chloroplasts. Plastids containing yellow or red pigments are called *chromoplasts.*

2. Examine under the high power several cells from the leaf of a moss, and study the chloroplasts. Make a drawing (10 cms. long) to show the number, form, and distribution of the chloroplasts.

E. THE CHLOROPHYLL

Collect green leaves of *Colocasia esculentum,* Gabi, *Araceae.* [8] Cut them into small pieces. Boil in water for a few minutes; then transfer to a small amount of 90 per cent alcohol. Describe what happens. Why are the leaves boiled in water before attempting to extract the chlorophyll? Examine the strong chlorophyll solution in direct sunlight. What is its color when held between the eye and the light? Then view by very strong reflected light and observe that its color is blood-red.

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[3] Almost any leaf, as of tomato, spinach, pea, tobacco, wheat, corn, etc.
[4] Chloroplast; from Gr. **chloros**, green; **plasma**, anything formed.
[5] Chlorophyll; from Gr. **chloros**, green; **phyllon**, leaf.
[6] Carbohydrate; from L. **carbo**, coal; Gr. **hydor**, water.
[7] Photosynthesis; from Gr. **photos**, light; **synthesis**, a putting together.
[8] Leaves of any green plant.

Every cell comes from another pre-existing cell. The usual way in which new cells are formed is by division. A single cell usually divides so as to form two new cells. One or both of these new cells may divide and give rise to other new cells. In cell division the *nucleus* is the controlling part of the cell. Cell division almost always takes place by a complicated process known as *mitosis,* or indirect division. [9] Before the cell divides, complicated changes take place in the nucleus. Then the nucleus divides. After the division of the nucleus, the *cytoplasm* divides, and a cross wall forms to separate the two resulting cells.

Examine under the high power of the microscope prepared slides showing the cells at the root tip of onion (*Allium cepa*) in various stages of division. With the aid of the instructor, draw five stages in mitosis.

1. Study first a cell in which division has not yet begun. Note the appearance of the cytoplasm. Distinguish in the resting nucleus: (a) The *nucleolus,* a roundish body which stains easily, (b) a *nuclear membrane,* which separates the nucleus from the rest of the cell, (c) the threadwork of *linin,* and (d) minute granules of *chromatin* [10] distributed along the linin threads. Draw.

2. Study a stage in which the chromatin has been changed into a single thick thread. Draw.

3. Next, find and study a stage in which the thread has become divided transversely into bodies called *chromosomes,* [11] which collect near the center of the nucleus. Draw.

4. Next, find a stage in which the chromosomes have divided longitudinally, and in which the two halves of the chromosomes have separated and moved to opposite sides of the cell. Draw.

5. Finally, study a stage in which a new cell wall has formed, and in which two new resting nuclei have developed. Draw.

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[9] **Mitosis**, from Gr. word meaning **thread.**

[10] Chromatin is so-named because it stains readily with dyes.

[11] Chromosome; from words meaning **color** and **body.**

IV. THE ROOT

In general the root grows downward into the soil, branching and spreading in all directions from the base of the stem. The root has two principal functions: (1) to hold the plant firmly in position in the soil, and (2) to absorb water and mineral substances from the soil. In structure, the root is characterized by a protective tip, the *root cap,* and by a radial arrangement of its fibro-vascular tissues.

A. TYPICAL ANCHORAGE OF PLANTS

Plants are held firmly in the soil in one of three different ways:

1. *By the tap root.* Dig up a one-year old seedling of *Leucaena glauca,* Ipil-Ipil, Leguminosae. [1] Wash off the soil and study the general habit of the root system. Note that there is one main descending root (tap root), and that there are numerous small branch roots and rootlets. What is the direction of growth of the tap root? The tap root is developed as a continuation of the radicle in the seed. What is the direction of growth of the lateral roots? Examine the tap root with a hand lens for contraction wrinkles. What advantage might there be in contraction of the roots? Make a drawing of the root system of *Leucaëna glauca.* Compare this tap root with the tap root of the beet and the radish, which are modified for food storage.

2. *By a number of large, strong, secondary roots.* In this case there may also be a tap root. This is the commonest method of anchorage of trees. Draw the exposed central part of the root system of *Ficus nota,* Fig, Moraceae. [2]

3. *By many roots that resist pulling strains.* As a class exercise, expose the base of the trunk of a coconut palm, *Cocos nucifera,* Palmae. [3] Count and record the number of roots. Expose a single long root for its whole length. Make a map-like diagram to show the directions taken by this root. Also make a diagram showing a cross section of the soil and the depth of the root at various distances from the base of the trunk. Measure its diameter and its length, and record these measurements. Are these roots stiff so that they are not easily bent? Do these roots resist pulling strains; in other words, do they possess tensile strength? Is the anchorage localized about the base of the palm, or is it distributed over the area penetrated by the

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[1] Almost any tree seedling.
[2] Almost any mature dicotyledonous tree.
[3] Any grass,—wheat, oats, corn, sorghum, etc.

roots? Explain why such a root system forms a serviceable anchorage.

Make a drawing of the connection between one of the main roots and a branch, extending the drawing to include a branch of the branch root. Name other plants having this type of anchorage.

B. ROOT HAIRS: ABSORPTIVE ORGANS

Oryza sativa, Rice, Gramineae [4]

1. Germinate seeds of rice on moist blotting paper in a moist chamber. After one week examine the roots that have been produced. Observe the covering of white hair-like growths on the roots. These are the root hairs. Do the root hairs extend to the very tip of the root? About how long is the region covered with root hairs? Is there any difference in length between the root hairs at different places in the region covered with root hairs? Make a drawing (10 cms. long) of the tip of the young root, showing root hairs.

Mount a thin cross section of the root cut through the root hair belt and study the structure of the hairs. Are the root hairs outgrowths from the epidermal cells? Is each root hair composed of a single cell (*unicellular*) or is it composed of several cells (*multicellular*)? What is the form of a root hair? Are its cell walls thick or thin? Does the plant need to constantly produce new root hairs?

Make a drawing (8 cms. long) of a single root hair, showing its connection with the root.

2. Germinate rice seeds on moist blotting paper covered with a thin layer of soil. Examine, with the hand lens and microscope, *root hairs* which have come in contact with the soil particles. Do the root hairs adhere to the soil particles? Soil is composed of small particles that are surrounded by films of water containing dissolved mineral substances that are necessary for plant growth. The water and mineral substances dissolved in it are absorbed by the root hairs and then move into the young root. Since the root hairs absorb water and dissolved materials, the root hairs are often called absorptive *organs*. Explain how the absorbing surface of the root is increased by the presence of root hairs. Do all plants produce root hairs? Examine the young roots of coconut, banana, and orange, for root hairs.

3. The mineral elements which must be absorbed by plant roots are nitrogen, sulphur, phosphorus, calcium, iron, magnesium and potassium. Two other elements which must enter through plant roots are hydrogen and oxygen; these enter chiefly as the compound, water. Soil which is without any one of these nine

[4] Wheat, oats, barley, corn, radish, etc.

elements cannot support plant growth. Substances containing one or more of the mineral elements just mentioned, which are added to the soil to increase plant production, are called *fertilizers*. Manures, bones, ashes, calcium phosphate, potassium sulphate, and ammonium sulphate, are examples of fertilizers. The effect of a fertilizer will depend upon the composition, the quantity used, the kind of plant, the kind of soil, and so forth.

C. THE ROOT CAP: THE PROTECTIVE STRUCTURE AT THE TIP OF THE ROOT

1. Examine, with a hand lens and low power of the microscope, the tip of a young root of rice, *Oryza sativa*, Gramineae,[5] on a seedling sprouted in a moist chamber. Observe the layers of cells that form a cap over the tip of the root. The root cap is a protective covering that prevents the soft tissues from being injured as the root grows through the soil. As the root pushes through the soil, the root cap continually wears away on the outside. At the same time, the root cap renews on the inside. Just back of the root cap new cells form by division. Some of these new cells replace the root cap cells, while others increase the length of the other parts of the root. Make a drawing (4 cms. wide), showing the root cap.

2. Draw a portion (10 cms. long) of the end of an aerial root of *Pandanus tectorius*, Pandan, Pandanaceae. These aerial roots finally grow into the soil and serve as prop roots. They have unusually large root caps. In general, root caps are proportional to the size of the roots.

D. APICAL MERISTEM AND EMBRYONAL TISSUES OF THE ROOT

Cocos nucifera, Coconut, Palmae[6]

1. With a sharp knife split the tip of the root of coconut and examine the cut surfaces with the hand lens. Do you find a root cap? Just back of this how many regions do you distinguish clearly?

2. Now mount in glycerin a thin median longitudinal section of the tip of a large root. Examine the cells just back of the root cap. A group of similar cells, such as these, is called a *tissue*. These cells have the power to divide, and after dividing, they enlarge. *Growth* consists in cell division, followed by cell enlargement and then by cell maturation. A tissue composed of cells having the power to divide is called *meristem* (from Greek *meristos*, divisible). This meristem near the apex of the root is called *apical meristem*. The division and subsequent enlargement of the cells of this meristem causes the root to increase in length. The immature tissues formed by meristem are called

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[6] Corn, wheat, oats, barley, or onion.
[5] Corn, wheat, oats, barley, onion, etc.

embryonal tissues. These are seen just back of the apical meristem. The layer of the embryonal tissue that forms the outermost layer of the root is called the *dermatogen* (meaning *skin-producer*). This consists of a single layer of cells that, by maturation, forms the epidermis that covers the mature root.

A number of layers just inside the dermatogen constitute the *periblem* (meaning something put around); this gives rise to mature tissues composing the *fundamental tissue system.* In the center of the root observe the cylinder of tissue called the *plerome* (meaning something which fills up). This develops principally into the *fibro-vascular*[7] *tissue system,* the most important function of which is the conduction of water and food. Just outside of the apical meristem lies the *calyptrogen* (meaning *cap-producer*), which is the embryonal tissue from which the *root cap* develops. Make a diagrammatic drawing, 5 cms. wide, showing each of the regions described above. Label carefully.

3. *Growth of roots in length.* The portion of the root near the tip shows cells in the three phases of growth, through which each cell or each group of cells passes in its development. The actively dividing cells of the apical meristem are in the *first phase of growth,* called the *phase of cell division.* The cells in the region of the embryonal tissues (*dermatogen, plerome, periblem,* and *calyptrogen*) are beginning the *second phase of growth,* called the *phase of cell enlargement.* A growth in length of the root as a whole takes place chiefly in the portion of the root in which the cells are in the phase of cell enlargement. Examine your specimen for cells that have already elongated. These will be found some distance back from the tip. These cells, which have reached their full size and have ceased to enlarge, are beginning the third phase of growth. In this phase changes occur in the cell walls and in the cell contents, and *mature* tissues are formed. Cells in this *third phase of growth* are said to be in the *phase of cell maturation.*

E. ABSORPTION BY ROOTS

Object: To demonstrate that dissolved substances are absorbed more rapidly by the root hairs than by the rest of the root surface.

Equipment. Rice seeds; filter paper; damp chamber; beeswax; methylene blue solution; slide; microscope.

Method. Germinate rice seeds on moist filter paper in a damp chamber. Make a small trough of beeswax on a microscope slide, and fill this trough with *methylene blue* solution. Place the roots of a rice seedling in the methylene blue solution and let the shoot be exposed to the air. Examine the root and root hairs under the microscope and determine whether the stain enters, and, if it enters, which parts it enters most rapidly. Discuss the results of this experiment.

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[7] Fibro-vascular; from L. **fibra**, a fiber; **vasculum**, a small vessel.

F. INTERNAL STRUCTURE OF A MONOCOTYLEDONOUS ROOT, AS SHOWN BY A TRANSVERSE SECTION

Colocasia esculentum, Gabi, Araceae [8]

Mount in glycerin a section cut with a razor from the mature tissue, and study it under the microscope. Make a diagram to show the positions of all of the tissues. Represent the whole cross section of the root by a circle 12 cms. in diameter. The outermost layer, composed of a single layer of cells covering the root, is the *epidermis* (meaning outer skin; from *epi,* upon; and *derma,* skin). Represent this in your diagram by a single line. Within the epidermis is a region composed of thin-walled, *parenchyma* cells. This is the *cortex,* [9] which belongs to the fundamental tissue system. Are all the cells of the cortex alike in shape and size? The cells of the cortex have three main functions: (1) transferring water from the epidermis to the center of the root, (2) by their turgor, maintaining the form of the root, and (3) storage of food. The innermost layer of cells of the cortex is a circle of thick-walled cells with an occasional thin-walled cell. This single layer of cortical cells is the *endodermis.* [10] Represent this by a circle composed of a single line properly placed in your diagram, and label it *endodermis.* Label the region lying beneath the epidermis and including the endodermis, *cortex or fundamental tissue.*

All of the tissue inside of the endodermis is the region called the *stele.* [11] The stele forms a central cylinder composed of several kinds of tissues. Label the circle of thin-walled cells just within the endodermis *pericycle;* [12] branch roots originate in the pericycle. The larger thick-walled groups of cells that radiate from the central part of the root compose the water-conducting *xylem* [13] or *wood;* represent these by a number of small circles, properly placed. Between the outer ends of the xylem rays are groups of cells which constitute the food-conducting *phloem;* [14] represent the phloem by shaded areas. The xylem and phloem, together constitute the *fibro-vascular tissue system.* The organization of xylem and phloem on alternating radii is called the *radial arrangement,* and this radial fibro-vascular arrangement serves to distinguish roots from stems. In the very center of the root are thin-walled, parenchyma cells, which form the *pith* or *medulla.*

2. Make a drawing under high power, of the width of three cells of the cortical parenchyma, extending from the epidermis to the pith, including one xylem ray and one phloem strand. Label each tissue. What is the function of the epidermis? Of the cortex?

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[8] Onion, corn, or smilax.
[9] Cortex; from L. **cortex,** rind or bark.
[10] Endodermis; from Gr. **endos,** within; **derma,** skin.
[11] Stele; from Gr. word meaning a post.
[13] From word meaning **wood.**
[12] Pericycle; from **peri,** around; **cyclus,** a ring or circle.
[14] From word meaning **bark.**

Of the pericyle? Of the phloem? How does water absorbed through the ordinary epidermal cells or through the root hairs reach the water-conducting xylem?

G. INTERNAL STRUCTURE OF A MONOCOTYLEDONOUS ROOT, AS SHOWN BY A LONGITUDINAL SECTION

Colocasia esculentum, Gabi, Araceae [15]

1. Examine a median longitudinal section of the root under the low power of the microscope. Make a diagram in the form of a rectangle about 10 centimeters wide. Show in your diagram the positions of each of the tissues. Represent each of the tissues as in the diagram of the cross section of the same root. Represent the epidermis by a single line, and the endodermis by another line. Shade the phloem. Represent the xylem by pairs of parallel lines, extending from the top to the bottom of your diagram.

The actual tissues included in your section will differ according to the way in which the section was cut from the root. Compare this section with your diagram of the cross section of the root. If a median section were cut along a radius on which lay a xylem ray, your section would show xylem but no phloem in the stele. On the other hand, if your section were cut along a radius on which phloem lay, your section would show phloem, but no xylem. Would it be possible to include both xylem and phloem in a median longitudinal section of this root?

2. Draw under high power three cells from the epidermis and about ten cells from the neighboring cortex. Also draw two cells from the endodermis and about four from the adjoining pericycle (outermost layer of stele). Examine the longitudinal section of a large water conducting vessel from the xylem. What is the form of the vessel? What sort of markings or thickened areas do you find on the walls of the vessel? Do you find vessels with thickened areas in the form of spirals and rings? The xylem vessel is a very long tube which has been formed from a chain of elongated cells placed end to end; the end walls, which separated the cells, have dissolved and the protoplasm has died. Make a drawing of one of the larger vessels and another of one of the smaller ones. Make your drawings 6 cms. long. Draw also about 5 cells from the pith.

H. INTERNAL STRUCTURE OF A DICOTYLEDONOUS ROOT, AS SHOWN BY A TRANSVERSE SECTION

Cambium and Growth in Thickness

Phaseolus lunatus, Lima bean, Leguminosae [16]

1. *Young root.*—Grow seedlings of *Phaseolus lunatus* in sawdust. Cut a thin cross section of a young root and examine under

[15] Onion, corn, or smilax.
[16] Other beans, cotton, potato, tomato, etc.

the microscope. Do the water-conducting xylem rays alternate with food-conducting phloem strands? Is the radial arrangement of the xylem and phloem conducting elements as clear in this section as in that of the *Colocasia* root? Make a circular diagram (12 cms. in diameter) of the transverse section of the root. As in the diagram of the transverse section of the monocotyledonous root, represent the epidermis by a single line, the endodermis by another single line, use small circles to represent the xylem rays, and shade the phloem areas. Label also *fundamental tissue or cortex, pericycle, stele, xylem, phloem, pith.*

Now examine very carefully, under the high power of the microscope, the regions just inside the phloem strands and just outside the arms of the xylem rays. You should see a layer of small, square-concerned *cambium* cells, containing dense protoplasm. *Cambium* is the meristem which causes growth in thickness. Dicotyledonous roots grow both *in length* and *in thickness.* Growth in length of roots takes place by the division and enlargement of the apical meristem. Cambium causes growth in thickness only. Such growth is called *secondary growth;* and the cambium which produces secondary growth is *secondary meristem.*

The cambium layer arises inside the phloem strands by cell division. These cambium cells, by dividing, give off xylem cells toward the center of the root and give off phloem cells toward the outside of the root. The cambium layers extend laterally and meet just outside of the original (or *primary*) xylem rays. There is thus formed a complete unbroken cylinder of cambium, which is called *cambium ring.* Represent the position of the *cambium ring* in your diagram by a single line, properly drawn, inside of the phloem strands and outside of the xylem strands. Label the original xylem rays *primary xylem* and the original phloem strands *primary phloem.*

The cambium is meristem composed of actively dividing cells. These new cells, formed by this division, on the inside of the cambium ring become *secondary xylem;* those on the outside become *secondary phloem.* But just outside of the primary xylem rays the cambium forms *pith ray cells,* not phloem.

2. *Old root.*—Examine under the microscope a cross-section of an old dicotyledonous root. Make a diagram of this 15 cms. in diameter. Indicate epidermis, cortex, and endodermis, in the same way as in the preceding diagram. Let a circle represent the cambium ring. Indicate the *secondary xylem* by small circles. Label the region between the areas of secondary xylem *pith rays* or *medullary rays.* These extend outward from the primary xylem. Just outside of the cambium that extends across each area of secondary xylem draw a line around the phloem area; label it *secondary phloem.* You should be able to see the small groups of *primary phloem* cells outside of the secondary phloem; if you do, label these areas.

Does the radial arrangement of xylem and phloem continue in the old dicotyledonous root? Do the roots of coconut, abaca, and banana show secondary growth in thickness? How do the monocotyledonous and dicotyledonous roots that you have studied differ in internal structure?

I. THE HYPODERMIS

Cocos nucifera, Coconut, Palmae

Examine on the same slide transverse sections of young and old roots of coconut. Note that just beneath the epidermis of the old root there is a ring of thick-walled cells called the *hypodermis* (meaning under the skin). Thick-walled cells of this sort are called *sclerenchyma* cells. Compare the young root with the old. Is there such a ring of thick-walled cells in the young root? By a thickening of the cell walls, cortical parenchyma in this region becomes changed into the hypodermis, composed of thick-walled, sclerenchyma [17] cells. In what phase of the growth of cells does such thickening of the walls take place? By what means are the walls thickened? Do you think that such sclerenchyma cells absorb water as readily as parenchyma cells? Does the old root of coconut absorb water as rapidly as the young root? The hypodermis, composed of sclerenchyma, is sometimes called *mechanical tissue*. From its location at the outside of the root do you think that it is most efficient in resisting pulling, bending, or crushing?

Draw small portions of young and of old roots. In each case, draw 4 cells of the epidermis and about twenty cells lying immediately beneath these.

J. ROOT TUBERCLES

Each student must bring his own specimens to class. Dig up specimens of *Phaseolus lunatus*, Patani or Lima Bean; or *Phaseolus radiatus*, Mungos or Green gram; *Mimosa pudica*, Macahia or Sensitive Plant; and *Leucaena glauca*, Ipil-ipil,—all belonging to the family Leguminosae. [18] The root system of each plant must be practically entire, and should be washed with the least possible injury to the tubercles.

1. Observe the small swellings called *tubercles* or *nodules* on the roots of these plants. Are these found on the smaller or on the larger roots? Are they most abundant on the younger or on the older roots? Are the tubercles more abundant near the surface of the soil than they are farther below the surface? Make a drawing showing a secondary root and its branches with the attached tubercles.

2. Crush a tubercle from one of these plants in a drop of water on a slide. Examine under high power. Observe the

[17] Sclerenchyma; from Gr. **skleros**, hard; **en**, in; **cheo**, pour.
[18] Any bean, clover, alfalfa, leguminous tree, etc.

minute, colorless organisms called *bacteria*. The bacteria cause the growth of the tubercles. These bacteria have the power to use the nitrogen gas from the air. They transform the nitrogen gas into substances which can be utilized by the legume. Legumes contain large quantities of nitrogenous compounds, and when their roots die the soil is enriched. For this reason, legumes are grown to increase the fertility of the soil. Legumes enrich the soil for other crops, such as corn and rice, which do not have tubercles. A leguminous crop is frequently plowed into the soil; in such cases it is called a *green manure*.

K. METAMORPHOSED ROOTS

A *metamorphosed*[19] root is one which is modified in structure, and which performs some function that is not performed by a typical root, or which performs the typical root functions under unusual conditions. What are the two principal functions of typical roots? Would a root modified for *food storage* be a metamorphosed root?

1. *Clinging roots of Piper betle,* Icmo or Betel Pepper, Piperaceae.[20] Examine the clinging roots. What is their function? In typical roots where is anchorage accomplished? May roots that are modified for attachment elsewhere be called metamorphosed? What kind of outgrowths do these roots have for attachment? Are these roots long? Are they branched? What is the response of these roots to light? Draw a small part of the stem showing clinging roots.

2. *Brace roots of Zea mays.* At what points do these roots appear? Do they become anchored in the soil like typical roots? Why are they of mechanical value? Are the roots of *Pandanus* similar? Draw the lower part of the stem of *Zea mays*, showing brace roots.

3. *Buttress roots of Parkia or Parashorea.*[21] Why are these roots of mechanical value? How are they placed with respect to the principal roots in the soil? Do the portions in the soil have all the functions of typical roots? Make a drawing of the base of the tree, showing buttress roots.

4. *The air-absorbing roots of Cocos nucifera.*[22] Examine an old root of coconut. From your previous exercise what can you say about the nature of the outer layers of the old roots of coconut? Would such layers prevent the entrance of air into the root? Is air necessary for the cells of the stele? Observe the short branch-roots which extend out through the hypodermis. They have large intercellular spaces, and their cells are covered with a waxy material. Their function is to supply the inner tissues of the main root with oxygen from the air. Draw a portion of a root, showing air-absorbing roots.

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[19] Meaning changed or modified in form; transformed.
[20] English Ivy and Boston Ivy.
[21] Cypress shows buttressed trunks.
[22] Cypress knees are similar.

5. *Spine roots of Dioscorea.* The principal roots of this plant contain large stores of food. Examine the spiny roots. These are borne on the surface of the ground, completely covering the storage roots beneath. What may be the function of these spiny roots? Draw a part of the spiny root.

6. *Roots in which food accumulates.* a. *Manihot utilissima,*[23] Camoteng-cahoy, Cassava or Tapioca Plant, Euphorbiaceae. Examine the stout, fleshy roots of this plant. Make a cross section of one with a pocket knife. Test a portion of the inner part of the root with iodine solution. What kind of food is stored in this root? Make a drawing of this root. Examine under the microscope a cross section of this root. Make a drawing (8 cms. across) of a single cell, showing starch grains. Such bodies, not a part of the protoplasm, are called cell *inclusions.* In what region of the root is the starch stored? Is the storage within or outside the cambium ring? Is it in the cortex or in the stele? Does this root also serve for absorption or anchorage?

b. *Dioscorea alata,* Yam, Ubi, Dioscoreaceae. Make a drawing of a storage root. Make a cross section of the root with a pocket knife. Test for starch. Examine with a hand lens. Is the food stored in the stele or in the cortex? Do these roots also serve typical root functions? Draw (8 cms. across) a single cell, showing starch grains.

c. *Ipomoea batatas,* Camote, Sweet Potato, Convolvulaceae. Draw a storage root. Make a cross section with a pocket knife; test for starch; determine whether storage is in cortex or stele. From the taste, what food do you know that this root contains besides starch? Do these roots also serve the typical root functions? Make a drawing (8 cms. across) showing a single cell containing starch grains.

L. ROOTS WHICH HAVE ECONOMIC VALUE

Collect as many useful roots as possible and fill out as far as possible the following table:

Common name of Plant.	*Scientific name.*	*Use to man.*	*Annual value to the P. I.*
Cassava	*Manihot utilissima* ..	....	....
Radish	*Raphanus sativus* ..	....	....
Sweet Potato ..	*Ipomoea batatas* ...	....	....
Yams, Ubi, etc..	*Dioscorea sp.*	....	....
Carrot	*Daucus carota*	....	....
Sincamas	*Pachyrrhizus erosus*.	....	....
Beet	*Beta vulgaris*	....	....
Turnip	*Brassica rapa*	....	....
....	....	....	....
....	....	....	....

[23] Beet, carrot, turnip, radish, etc.

V. THE STEM

A typical plant is composed of two main parts: (1) the root, which in general grows downward into the soil; and (2) the *shoot,* which grows upward into the air and is composed of *stem* and *leaves.* The typical stem is nearly cylindrical in form. The stem is always composed of *nodes,* which are the points at which leaves and branch stems are borne; and of *internodes,* which are the portions between the *nodes.* The stem may be regarded as having two principal functions. One of these functions it to support, by its own strength, the leaves in such a position that they will receive light and air, which are necessary for the performance of the leaf functions, and to support the reproductive structures, flower and fruit, in an advantageous position. The other function is to conduct water and dissolved mineral substances upward from the roots to the leaves, and to conduct prepared food downward from the leaves, where it is manufactured, to places where it is used or accumulates.

A. EXTERNAL FEATURES OF THE STEM OF A DICOTYLEDONOUS PLANT

Psidium guajava, Guava, Myrtaceae [1]

1. Examine a large twig of guava. What is the form of the stem? Note that the stem bears certain lateral appendages which are leaves. The points on the stem at which leaves are borne are called *nodes;* the portions of the stem between the nodes are *internodes.* Note also the other lateral outgrowths which are *branch stems.* Observe that branch stems originate in the *axils* of the leaves, that is, in the angle between the leaf and the main stem. At the apex of the stem find a *bud.* A *bud* is an *undeveloped shoot,* composed of stem and ordinary leaves or of stem and floral leaves. Make a drawing of the apex of the stem. Make another drawing to show the origin of a branch stem.

B. APICAL MERISTEM AND EMBRYONAL TISSUES OF THE STEM

Examine under the microscope a thin median longitudinal section of the apex of a stem. Find the actively dividing cells at the very apex, which constitute the *apical meristem.* These cells are dividing and are in the first phase of growth. Just behind the apex locate the *embryonal tissues.* Are these as clearly distinguishable as those at the tip of the root? The cells of the embryonal tissues are immature, but are beginning to enlarge; that is, they are beginning the second phase of growth. The embryonal tissue that forms a single layer at the outside of the stem

[1] Almost any woody plant; e. g., peach, apple, pear, oak.

is the *dermatogen,* which develops into the *epidermis.* Below the dermatogen locate the *periblem,* which forms the fundamental *tissue system or cortex.* And at the center of the stem find the cylinder of embryonal tissue that gives rise to the *stele,* the most important part of which is the *fibro-vascular tissue system.* Do you find on the stem a structure similar to the root cap? Study the very young leaves. Note that *buds,* which later develop into branch stems, occur in the axils of the leaves. Make a diagrammatic drawing to show the points mentioned above.

C. GROWTH OF STEMS

Object: To determine the rate of elongation of a dicotyledonous stem and to determine the region of most rapid elongation.

Equipment. Ganong space-marking wheel; India ink; sheet of glass; a healthy dicotyledonous plant in the field; a rule graduated into centimeters and millimeters.

Method. Select a suitable plant. Spread India ink in a thin layer on the sheet of glass. Ink the rubber stamp of the space-marking wheel. Carefully mark the stem from its apex to a base mark about ten cms. below the apex. These marks should be cross lines two mm. apart. The base mark should be very distinct. Allow the ink to dry; then measure the exact distance from the base mark to the apex. After three days remeasure the distance from the base mark to the apex. How much has the stem elongated? What is the daily rate of elongation for this period? Cut the stem; quickly carry it to the laboratory; and make a diagram to show the exact lengths of the spaces which were originally two mm. In what region is growth in length most rapid? How far from the apex has the stem stopped growing?

D. INTERNAL STRUCTURE OF A MONOCOTYLEDONOUS STEM

Cocos nucifera, Coconut, Palmae [2]

Study a transverse section of a coconut stump. The hard, nearly cylindrical parts that are scattered throughout the stem are the *fibro-vascular bundles.* The bundles are composed of tough material and aid in giving strength to the stem. They also conduct water and dissolved salts up the stem, and conduct prepared foods down the stem. Examine a bundle with the hand lens. Can you see the large water-conducting xylem tubes? Estimate the number of bundles, and record your estimate. Are these bundles distributed uniformly throughout the cross section of the stem. If not, describe their distribution. Where are the largest bundles? At the outside of the stem do you find a cylinder of hard tissue? In what way is it of value to the plant? Make a diagram (10 cms. in diameter) of a transverse section

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[2] Corn.

of the coconut stem; in your diagram shade the outer, hard portion, and represent the fibro-vascular bundles by means of circles, properly distributed.

E. INTERNAL STRUCTURE OF A MONOCOTYLEDONOUS STEM, AS SHOWN BY A TRANSVERSE SECTION

Zea mays, Corn or Maize, Gramineae [3]

1. Examine the cut end of stem of *Zea mays*. This transverse section shows that the outer part of the corn stem is a thin shell of hard tissue. Within this hard tissue is a very soft pith, in which fibro-vascular bundles are scattered. Tear a portion of the stem lengthwise. How long are the bundles? What is the value to the plant of the hard outer portion of the stem? What are the functions of the *fibro-vascular bundles?* Is the structure of the corn stem essentially like that of the coconut? What gives rigidity or stiffness to the stem?

2. Examine under the low power of the microscope a thin transverse section of the corn stem. Of what kind of tissue is the outer shell of hard material composed? What type of cells compose the pith? Make a diagram (10 cms. in diameter) of the cross section of the stem. Let a double line represent the *sclerenchyma cylinder* at the outside, and indicate the distribution of the fibro-vascular bundles by small circles.

3. Make a drawing (10 cms. in diameter) of the transverse section of a single fibro-vascular bundle, as seen under the high power of the microscope. The outer layer of thick-walled cells surrounding the bundles is called the *bundle sheath.* Does this extend completely around the bundle? Note the *xylem* portion of the bundle, toward the center of the stem. In it observe the two large *xylem vessels.* Between these large water-conducting vessels do you find another smaller vessel? Do you find a large cylindrical *intercellular air space* in the xylem? The tissue composed of thin-walled cells in the xylem region is called *xylem parenchyma* or *wood parenchyma.*

In the phloem region the larger cells are *food-conducting sieve tubes.* These are tubes composed of cells placed end to end in rows, and separated by walls containing holes through which the cell contents may pass from cell to cell. The smaller cells, which are filled with protoplasm, are *companion cells.* This type of bundle is called a *collateral bundle,* because the xylem and phloem lie side by side. The xylem lies toward the center of the stem, and the phloem nearer the outside of the stem. Do you find *cambium* between the xylem and the phloem? A bundle of this type is also a *closed* bundle, because it contains no cambium, and therefore cannot enlarge. Monocotyledonous plants are characterized by closed collateral bundles.

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[3] Wheat, oats, barley, sorghum, Kaffir corn, etc.

4. Draw 4 pith cells, as seen under the high power of the microscope. Describe the contents of these cells. Do they contain any chlorophyll? Do they contain starch grains? Draw, under high power, 4 sclerenchyma cells from the hard tissue of the outside of the stem. This tissue is composed of cells of the *fundamental and epidermal tissue systems.*

F. INTERNAL STRUCTURE OF A YOUNG DICOTYLEDONOUS STEM

Manihot utilissima, Cassava, Euphorbiaceae [4]

Examine, with the low power of the microscope, a transverse section of a young stem. Find, at the outside, the single layer of cells composing the *epidermis.* Inside of this, locate the *primary cortex* (*fundamental tissue system*). Within the primary cortex is the stele, which forms a central cylinder, containing the *fibro-vascular tissue system.* See whether you can distinguish the *endodermis* or *starch sheath.* It is the innermost layer of cells in the primary cortex. It is usually not so easily distinguished as is the endodermis of the root.

Within the stele observe the *fibro-vascular bundles,* which are arranged in a ring. Examine one of these bundles under the high power of the microscope. Note that the *xylem* portion of the bundle is placed toward the center of the stem, and that the *phloem* portion is placed away from the center of the stem. Which is larger, the xylem part of the bundle or the phloem part? Is this difference in size probably related to the fact that the stem conducts a greater volume of water than of food? Notice that the phloem is separated from the xylem by a layer of square-cornered cells that are densely filled with protoplasm. This layer which lies between the xylem and the phloem, is the *cambium.* Note that the cambium of one bundle is connected with the cambium of neighboring bundles. The cambium in the bundles is called *fascicular* [5] *cambium,* and that extending from one bundle to another is called the *interfascicular cambium.* Thus the cambium forms a complete cylinder, called, from its appearance in transverse section, the *cambium ring.* The cells of the cambium are in a state of active cell division. The new cells formed on the inner side of the cambium in the bundles enlarge and become xylem; those on the outside become phloem cells. Thus the cambium causes an increase in diameter of the stem. Examine that part of the stele which lies just outside of the vascular bundles; this is the *pericyle.* Find the cylinder of parenchyma cells at the very center of the stele; this is the *pith* or *medulla.* The rays extending outward from the pith form the *primary pith rays or primary medullary rays.* These lie between the bundles. What is the color of pith? What type of cells

[4] Castor-bean, bean, tomato, cotton, etc.; they exhibit minor fluctuations. Aristolochia, though not of economic value, is perhaps most clear.

[5] **Fascicular**; from **fasciculus**, a small bundle.

composes the pith? What is the appearance of the contents of the pith cells?

Observe now the primary cortex more closely. What is its color? Do the cells contain chloroplasts? What is one of the functions of the cortex? What types of *mechanical tissue* do you find in the cortex? Tissue that is composed of cells that are thickened only at the corners is called *collenchyma.* Find a cylinder of this kind of mechanical tissue in the cortex. Do you find any sclerenchyma in the stele? Is the pericycle sclerenchymatous? Are the bundles surrounded by a sheath, as they are in maize? Make a diagram (12 cms. in diameter) showing all of the tissues found in the stem. Draw no cells, but indicate positions of tissues. Represent the epidermis by a single line. Draw a line around each of the areas occupied by vascular bundles. Represent the cambium by a single line.

Make a drawing under high power of a single fibro-vascular bundle. Label *water-conducting xylem, food-conducting phloem,* and *cambium.* Are these bundles *open?* Are they *collateral?* What are the principal differences between this stem and the stem of *Zea mays?*

G. INTERNAL STRUCTURE OF AN OLD DICOTYLEDONOUS STEM, ILLUSTRATING GROWTH IN THICKNESS BY THE ACTIVITY OF THE CAMBIUM

Manihot utilissima, Cassava, Euphorbiaceae [6]

With a pocket knife cut transverse and longitudinal sections of the old stem of *Manihot utilissima.* Examine these with a hand-lens. In what ways does the central *pith* differ from the cylinder of wood which surrounds it? Can you distinguish the pith rays? The region outside of the wood is the *bark.* Does it separate readily from the wood?

Transverse section.—Examine a thin transverse section of the old stem under the microscope. For comparison have on the same slide the transverse section of the young stem. Observe all the changes that have taken place as the stem has grown older. Find the *pith* at the center of the stem. Do you observe any differences between the pith in the young stem and the old stem? Record these.

The cylinder of *wood* surrounds the pith. From what tissue of the young stem is the wood formed? Is the wood composed principally of *xylem?* What tissue do you find in the wood besides xylem? Observe the character of the *pith rays* that run outward through the wood. What are their functions? Find the *cambium* ring just outside the wood. The cambium cells have very thin walls, with square corners, and are filled with protoplasm. The cambium cells divide and form new cells. The new

[6] See foot-note for preceding exercise.

cells toward the center of the stem enlarge and mature and become wood or xylem, while those toward the outside develop into phloem. Thus the growth of the wood takes place at its outer surface, while the growth of the bark takes place at its inner surface. What changes take place in the xylem as the stem grows older?

Examine now the tissues outside of the cambium ring; this region extending from the cambium to the outside of the stem is the *bark*. Just outside of the cambium find the *phloem*. What is the principal function of the phloem? Do you observe any difference between the young and the old stem in the appearance of the phloem? Can you distinguish *sieve tubes* and *companion cells* in the phloem? Can you find any other type of cells in the phloem? In the portion of the bark just outside the phloem do you observe any differences between the old and young stems? Can you distinguish the *endodermis* or *starch sheath?* This is the innermost layer of cells of the primary cortex and forms the boundary line between the primary cortex (*fundamental tissue system*) and the *stele* (containing the *fibro-vascular tissue system*).

What changes do you find in the *cortex?* Explain these changes. Do you find any new types of cells appearing in the old stem? Are there any changes in the green parenchyma (*chlorenchyma*) cells of the cortex? Do you find any new type of *mechanical* cells in the old stem?

Look for the *epidermis*. Is the epidermis present on the old stem? Do you find any new cells (*cork*) just beneath the epidermis, or replacing the epidermis of the young stem? Do you find openings (*lenticels*), connecting with the air? What is the function of lenticels?

Make a diagram (10 cms. in diameter), showing all the regions which you have observed. Draw no cells; indicate the regions by areas, surrounded by lines. Label accurately the regions of all tissues. Make another drawing under high power of the microscope of a narrow strip extending from the outside to the center of the stem. Label carefully.

What are the chief differences between monocotyledonous stems and dicotyledonous stems? Make a table to show these differences.

Median longitudinal section of the old stem.—Examine a thin section under the low and the high power of the microscope. Have your drawings of the cross section of this stem before you, for comparison. Locate each of the tissues shown in your diagram of the transverse section. Draw a few cells of each of the tissues under high power.

Erythrina indica, Dap-dap, Leguminosae [7]

1. *Transverse section.*—Examine the transverse section under low and then under high power of the microscope. Note all of the tissues that occur from the outside to the center of the stem. Locate the *bark* of the tree. This is the tissue extending from the cambium-ring to the outside of the stem. At the outside note the box-like brown cells of the *cork.* Below this note the thin-walled cells that constitute the *phellogen or cork cambium,* which gives rise to the *cork.* This cork cambium produces cork on the outside and parenchyma cells on the inside. Locate the cortex. What are the functions of the cortex? Find the *cortical parenchyma.* Does it contain chlorophyll? Find the *food-conducting phloem.* Do you also find thick-walled cells, called *bast* fibers, in the phloem region? Locate the *cambium.*

Obtain a short piece of stem about 2 cms. in diameter. Examine with a hand-lens the cut end of the stem. Try to tear away the bark. Note that the bark separates easily from the wood. The cambium cells are thin-walled and readily tear.

Now examine, with the microscope, the wood, composed of the tissues within the cambium ring. Observe the pith rays, radiating through the wood. What is the radial extent of these? Do you find short pith rays, called *secondary pith rays?* What is the probable function of the pith rays? Note the large-pored *water-conducting vessels of the xylem.* Note also the smaller water-conducting elements, called *tracheides,* which surround the vessels. Observe the thin-walled *wood parenchyma cells.* Find the groups of *wood fibers,* which are thick-walled cells occurring in broken rings. Make a circular diagram (10 cms. in diameter) showing the position and extent of each of these tissues. Draw no cells; only indicate and label areas.

Make a drawing, with the aid of the high power of the microscope, showing: a vessel, several tracheides, a few cells of the wood parenchyma, several wood fibers, and a medullary ray.

With the specimen before you, answer the following questions: 1. What is the relative size of vessels, wood cells, wood fiber cells, and medullary ray cells? 2. Do you observe starch in any of the cells? If so, in which ones? Stain your section with iodine solution, if necessary. 3. What is the radial extent of the pith rays? How many cells in width are the medullary rays? What is the function of the medullary rays? 4. What is the relative thickness of the walls of the vessels, tracheides, wood cells, and wood fibers?

2. *Radial longitudinal section.*—How is the radial section cut? Demonstrate with a small piece of the stem and a pocket

[7] Oak.

knife. Why is it called a radial section? Study a thin radial longitudinal section under the microscope. Note the appearance of the pith rays. What is the vertical extent of these rays? The radial extent? What is the length of the vessels What is the form of the vessels? Note the thickening of the walls of the vessels. How were the pits formed? What is the function of the pits? Do you observe any *spiral, scalariform* (ladderlike), or *annular* (ring-shaped) thickenings of the walls of the vessels? If so, where? What is the length of the wood cells, as compared with the diameter? How does the vertical height (length) of the wood cell compare with that of a pith ray cell? Of a vessel? What is the nature of the thickening of the walls of the wood cells and of the tracheides? Look for *wood fibers*. How does a wood fiber compare in length with a vessel? With a wood parenchyma cell? With a pith ray cell?

Make a drawing showing a portion of a vessel, several wood cells, several tracheides, several wood fibers, several pith ray cells.

3. *Tangential longitudinal section.*—What is a tangential section? Demonstrate with a pocket knife how you would cut a tangential section from a stem. Then study a very thin tangential section under the microscope. Look for pith rays. What is the vertical extent of a pith ray? Determine the tangential extent of a pith ray. Does this section show the radial extent of a pith ray? Do the vessels have the same appearance as in the radial section? Why? Do the wood cells in tangential section appear different from those in the radial section? Examine the wood fibers. What is their function? What do you note about the way in which the fibers fit together? Of what advantage is this? Make a drawing showing a vessel, several wood cells, several tracheides, several wood fibers, and a medullary ray.

I. FUNCTIONS OF STEMS

1. *Support:* holding the leaves and reproductive structures in a favorable position for the performance of their functions. Three typical ways in which necessary rigidity is maintained.

a. In plants that are not woody, by the turgor of tissues composed of thin-walled cells. Obtain a turgid stem of an herb. Note that the stem is rigid and able to support the leaves. Now place this stem in a concentrated solution of common salt, sodium chloride. What change do you note in rigidity? To what is this change due?

b. In monocotyledonous plants, by a hollow cylinder or tube of sclerenchyma, at or near the outside of the stem. Examine by means of the hand lens and microscope, cross sections of the stems of rice, corn, and sugar cane. Make diagrams (4 cms. in diameter) of these, shading the sclerenchyma regions.

c. In dicotyledonous trees and shrubs, by a massive development of woody structures, mostly xylem, formed in the growth in thickness resulting from the activity of the cambium. Examine by means of the hand lens cross sections of the stems of six kinds of dicotyledonous trees or shrubs. Make diagrams (4 cms. in diam.); shade the woody portions.

2. *Conduction:* furnishing a way for the movement of materials between the roots and leaves.

a. Conduction of prepared foods: carbohydrates, fats, and proteins. These materials move principally downward in the stem; and the movement takes place almost exclusively in the sieve-tubes in the phloem portion of the fibro-vascular bundles. Review your drawings and notes on the structure of the phloem.

b. Conduction of water and dissolved mineral salts. These move upward through the vessels and tracheides of the xylem. Cut under water a translucent colorless shoot, such as that of *Impatiens;* place the cut end in a solution of *eosin* (a red stain); and observe the rise of the colored solution in the stem. Does the colored solution also enter the leaf? Cut cross sections of the stem and determine the place of occurrence of the red color. Repeat this experiment with a shrubby plant.

J. METAMORPHOSED STEMS

A *metamorphosed stem* is one which is modified in structure and which performs some function that is not performed by a typical stem, or which performs the typical stem functions in unusual ways.

1. *Stems of climbing plants.* a. The stem of a plant climbing by means of roots. *Piper betle,* Icmo or Betel Pepper, Piperaceae.[8] Note that this stem cannot be considered typical, because it produces a number of roots for climbing, and because it is chiefly modified for conduction, not support of leaves by its own strength. It possesses tensile strength rather than rigidity. Draw a small portion of this stem.

b. Twining stems: *Dioscorea alata,* Ubi, Yam, Dioscoreaceae, or *Psophocarpus tetragonolobus,* Calamismis, Leguminosae.[9] Why must this be considered metamorphosed? Draw a small portion that is twining about a support.

c. Tendrils: *Cucurbita maxima,* Calabaza, Cucurbitaceae.[10] Note the *tendrils* used for climbing. How do you know that these tendrils are stems and not leaves? Why are they considered to be metamorphosed stems? Draw a tendril, wound about a support.

2. *Stems which carry on photosynthesis and accumulate water.*[11] *Nopalea cochinelifora,* Dilang-baca, Cactaceae. Where

[8] English Ivy or Boston Ivy.
[9] Any twining bean.
[10] Almost any gourd, or grape.
[11] **Opuntia; Asparagus** for photosynthesis.

are the leaves of this plant? Why must the stem be regarded as metamorphosed? Draw a portion.

3. *Stems which accumulate food and reproduce the plant.* a. *Runner: Ipomoea batatas,* Camote, Sweet Potato, Convolvulaceae. A *runner* is a stem that grows along the surface of the ground, and sends roots into the ground and branch stems into the air. Explain why this must be considered a metamorphosed stem. Draw.

b. *Rhizome:*[12] (1) *Imperata cylindrica, var. Koenigii,* Cogon, Gramineae. A *rhizome* is a horizontal stem or branch growing underground. What are the differences between a *runner* and *rhizome?* Describe the appearance of the leaves on the rhizome. How does cogon spread so rapidly? Define rhizome and explain why it must be regarded as a metamorphosed stem. Draw. (2) *Maranta arundinacea,* Arrow root, Marantaceae. Find the leaves borne on this underground stem. How do you tell a storage root from a storage stem? Explain why this is regarded as metamorphosed. Draw. (3) *Zingiber officinale,* Ginger or Luya, Zingiberaceae. What differences do you note between this rhizome and that of *Maranta?* What difference is there in the materials stored? Draw. (4) Study and draw the rhizome of Banana, *Musa sapientum,* or Abacá, *Musa textilis.*

c. *Tuber: Solanum tuberosum,* Potato, Solanaceae. A *tuber* is a rhizome thickened at the end. Do you find leaves? Draw this tuber.

d. Corm: (1) *Amorphophallus campanulatus,* Puñgapung, Araceae.[13] (2) *Colocasia esculentum,* Gabi, Araceae. Do you find starch? Do you find leaves? Draw this corm. A corm is a sort of rounded tuber. Draw.

e. Bulb: *Allium cepa,* Onion, Liliaceae. Locate the stem portion. A bulb differs from a corm in being covered with many thick scales. Where is the storage? Draw.

K. STEMS WHICH HAVE ECONOMIC VALUE

Examine as many kinds of useful stems as possible. Fill out the following table as far as you can.

1. Underground stems.

Common name plant.	Scientific name of plant.	Use to man.	Annual value to P. I.
Ginger	*Zingiber officinale* ..	....	....
Arrowroot	*Maranta arundinacea*	....	....
Gabi	*Colocasia esculentum*	....	....
Yautia	*Xanthosoma sp.*	....	....
Potato	*Solanum tuberosum* ..	....	....

[12] Iris, Polygonatum, Spartina, etc.
[13] Crocus.

2. Above-ground stems.
Entire stem.

Common name plant.	Scientific name of plant.	Use to man.	Annual value to P. I.
Asparagus	*Asparagus officinalis-*	....	....
Bamboo	*Bambusa spp.*	....	....
Gogo	*Entada scandens* ...	....	....
Rattan	*Calamus spp.*	....	....
Sweet Potato ..	*Ipomoea batatas* ...	....	....
Commonest stems used for firewood	*Leucaena glauca, etc.*	....	....

3. Above-ground stems.
Wood only.

Common name plant.	Scientific name of plant.	Use to man.	Annual value to P. I.
Narra	*Pterocarpus indicus* .	....	....
Ipil	*Intsia bijuga*	....	....
Tindalo	*Pahudia rhomboidea.*	....	....
Camagon	*Diospyros discolor..*	....	....
Ebony	*Diospyros ebenum ..*	....	....
Molave	*Vitex parviflora* ...	....	....
Dungon	*Heritiera littoralis..*	....	....
Guijo	*Shorea guiso*	....	....
Catmon	*Dillenia philippinensis*	....	....
Santol	*Sandoricum koetjape*	....	....
Tanguile	*Shorea polysperma..*	....	....

4. Above-ground stems.
Bark.

Common name plant.	Scientific name of plant.	Use to man.	Annual value to P. I.
Cork	*Quercus suber*	....	....
Cinchona (quinine)	*Cinchona spp.*	....	....
Mangrove swamp trees	*Rhizophoraceae, family*	....	....
Flax	*Linum usitatissimum*	....	....
Jute	*Corchorus capsularis*	....	....

5. Above-ground stems.
Liquid from stems.

Common name plant.	Scientific name of plant.	Use to man.	Annual value to P. I.
Nipa	*Nipa fruticans*	....	....
Buri	*Corypha elata*	....	....
Coconut	*Cocos nucifera*	....	....
Sugar cane	*Saccharum officinarum*	....	....
Almaciga	*Agathis alba*	....	....
Para Rubber ..	*Hevea brasiliensis* ..	....	....
Pine	*Pinaceae, family* ...	....	....

L. TREATMENT OF STEMS

1. *Pruning.* What is meant by *pruning?* Discuss the possible advantages or uses of pruning.

2. *Graftage.* Define *graftage, cion,* and *stock.* Explain why the possibility of grafting depends upon the ability of the cambium of the cion to unite with the cambium of the stock. Why can not monocotyledonous plants be grafted? Describe the methods used in graftage. Explain the benefits or uses of graftage. How does *budding* differ from *grafting?*

3. *Treatment of wounds.* Discuss methods of treating wounds in valuable trees.

4. *Propagation by cuttings.* Describe the ways in which plants may be grown from stem cuttings. Discuss the advantages of propagating plants by means of cuttings. Name five plants which can be propagated easily by means of cuttings, five which are difficult to propagate in this way, and five which cannot be propagated by cuttings. From what tissue is the cushion of new cells (the *callus*) at the base of the cutting formed?

VI. THE LEAF

In origin, the leaf appears as a lateral outgrowth on the stem. Leaves are situated at *nodes* and bear branch stems in their *axils.* In structure, the typical leaf is a flattened, expanded organ, without nodes or internodes. The leaf is typically green in color. The growth of the leaf is usually definitely *limited,* while the growth of the stem is more likely to continue throughout the life of the plant. The principal function of the leaf is to expose green chlorophyll tissue to the light and gases of the atmosphere, so that this tissue can manufacture food by the process of *photosynthesis.* Another important process with which leaves are concerned is the evaporation of water, or *transpiration.*

A. THE PARTS OF THE LEAF

1. Examine the leaves of five economic plants. Observe that the leaf may be divided into three parts: (1) the *blade* or *lamina,* which is the green expanded portion, (2) the *leaf-stalk* or *petiole,* and (3) the base. When the petiole is lacking, the leaf is *sessile.* [1] Frequently the base is modified to form two small, flattened parts called *stipules.* Make an outline drawing (10 cms. long) showing one of the leaves.

2. Hold the leaf up to the light and note the framework formed of *veins.* The large central vein is the *midrib;* the smallest veins are *veinlets.* On which surface are the veins most easily seen? Draw the principal veins in a small portion of a leaf. The veins and midribs constitute the *fibro-vascular bundles* of the leaf. The arrangement of the veins in the leaf is termed the *venation.* Examine the netted-veined leaf of *Canangium odoratum,* Ilang-ilang, Anonaceae. [2] Note that the veins form an irregular network. This type is characteristic of Dicotyledones. Draw a small portion of the leaf. A second type of venation is characteristic of Monocotyledones. Examine the leaf of *Zea mays,* maize, Gramineae, and note the *parallel-venation.* The principal branches of the bundles run parallel to each other. Draw a small portion of this leaf. How does the venation of abaca and banana differ from that of maize? How is the venation of *Dioscorea* exceptional?

B. DESCRIPTIVE TERMS APPLIED TO LEAVES

The shape, texture, kind of surface, and arrangement of leaves are frequently valuable characteristics in descriptive and systematic botany, because they are often of use in classifying plants.

[1] Sessile; from L. sessilis, low; from sedere, sessum, to sit.
[2] Beans, tomato, grape, etc.

While flower and fruit characters are most useful in distinguishing the families and genera of plants, leaf characters are often of great value in distinguishing one species from another in the same genus. [3]

1. *Simple and compound leaves.* A simple leaf has a single blade arising from the petiole or base, while a compound leaf has its blade separated into parts. By means of diagrams made by the instructor learn to distinguish various kinds of compound leaves. Collect specimens and draw as many as possible of the following types: pinnate, bipinnate, tripinnate, palmately compound, decompound.

2. *Margin.* Collect specimens and draw the following types: entire, serrate, dentate, crenate, repand, sinuate, incised, lobed, cleft, parted, divided.

3. *General outline.* Draw the following types: linear, lanceolate, oblanceolate, oblong, ovate, obovate, elliptic, cuneate, spatulate, cordate, reniform, orbiculate, peltate, auriculate, hastate, sagittate.

4. *Apex.* Draw the following types: acuminate, acute, obtuse, rounded, truncate, retuse, emarginate, obcordate, cuspidate, mucronate, aristate.

5. *Base.* Draw the following types: rounded, cordate, auriculate, sagittate, hastate, acute, cuneate, decurrent, attenuate.

6. *Texture.* Study the following types: herbaceous, membranaceous, papyraceous, chartaceous, coriaceous.

7. *Arrangement on stem.* Draw the following types: alternate, spiral, opposite, decussate, verticillate.

8. *Trichomes.* Study the following types: ciliate, silky or sericeous, hirsute, pubescent, glandular-pubescent, tomentose, glaucous, glabrous.

C. PROTECTION OF BUD AND GROWTH

Examine the growing tip of the shoot of *Dioscorea alata,* Ubi or Yam, Dioscoreaceae. [4] What can you say about the age of a leaf with respect to its distance from the apex of the shoot? Of two successive leaves on the shoot, which one is the older?

Observe the size of the leaves. How far from the apex are the leaves that have reached their full size? How do the mature leaves differ in shape from the young ones?

Observe the length of the successive internodes. How far from the apex of the stem are the internodes of greatest length? How does this distance compare with that for mature leaves?

Explain in what way this specimen illustrates the *limited* growth of leaves and the relatively *unlimited* growth of stems.

Note the protection of the apex of the shoot. Against what danger is the apex protected? By what means is this protection

[3] Almost any large dictionary shows diagrams illustrating leaf shapes.
[4] Beans.

secured? Of what advantage is the fact that the very young leaves grow faster than the stem on which they are borne?

Note that the young leaves are closely appressed to the stem. This is brought about by the more rapid growth of the lower leaf surface than of the upper. The older leaves stand out from the stem at an angle. This is due to more rapid growth on the upper surface than on the lower. Does this change from more rapid growth on the lower surface to more rapid growth on the upper surface chiefly depend upon internal or upon external conditions?

Do the very young leaves grow more rapidly than the stem? In what region does the stem grow more rapidly than the leaf? Of what advantage is the fact that most of the elongation of the stem takes place before the leaves are fully expanded?

Make a drawing (X 2) of the tip of the shoot to the place where the leaves are 15 mm. long. Give the length of the internode above each leaf. Indicate the direction of the axis of the stem, and in your drawing let this be vertical. Make a similar drawing (X 1) from the point where the leaves are 15 mm. long to the point where the leaves are mature. Give the length of the internodes and the direction of the axis as before. Label both drawings carefully.

D. STRUCTURE OF THE LEAF

Epidermal Tissue System

The epidermal tissue system of the leaf is remarkable in exhibiting many variations and modifications, which are related to the conditions under which the plant lives. This tissue system is derived from the dermatogen. It consists of three tissues: (1) *epidermis,* consisting of a single layer of cells (2) the *trichomes* (hairs), and the (3) *stomatal guard cells* (surrounding pores connecting the external atmosphere with the internal spaces in the leaf).

1. *Epidermis of the leaf.* a. Strip the epidermis from the leaf of *Musa textilis,* abaca, Musaceae;[5] or cut thin surface-sections from the leaf. Study the epidermis under the microscope. Are the lateral walls of the epidermal cells thick or thin? Are there any intercellular spaces between the epidermal cells? What is the nature of the contents of the cells? Do you find chlorophyll in the epidermal cells? Make a drawing (2 cms. wide) under high power of the microscope, showing four cells from the upper epidermis. Make a similar drawing showing four cells from the lower epidermis.

Study now a cross section of the epidermis of *Musa textilis.*[6] What do you notice about the thickness of the outer walls as compared with the lateral walls and of the inner walls? The epidermis separates the internal tissues of the leaf from the external

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[5] Onion, beet, tomato, etc.
[6] Onion, beet, etc.

medium; it protects the internal tissues against injury due to drying, and against mechanical injury by rain, dust, insects, fungi, bacteria, and so forth. Make a drawing (2 cms. wide) of four cells of the upper epidermis. Make a drawing of four cells of the lower epidermis.

b. Study in a similar manner the stripped epidermis or thin surface-sections of the leaf base of *Saccharum officinarum*, Tuba or Sugar cane, Gramineae. Note the layers of wax. What may be the functions of such wax layers? Make a drawing showing the surface of the epidermis. Also, examine and make drawings of these epidermal cells as seen in cross-section.

c. Make a drawing (2 cms. wide) of four epidermal cells, as seen in cross section, of the leaf of *Furcraea gigantea*, Mauritius Hemp, or of *Agava sisalana*, Sisal Hemp. [7] Note the thick layers of cuticle and wax that extend over the surface of the epidermis. Cuticle and wax are very impervious to water. Are the layers of cuticle and wax thicker on the upper or on the lower surface of the leaf? What is the function of the cuticle and wax?

2. *Trichomes.* Trichomes are outgrowths of the epidermal tissue. They are classified according to their structure into the following kinds: (1) *Simple hairs.* Composed of single cells or single rows of cells. Each hair is borne by a single epidermal cell, or is produced from a single epidermal cell. (2) *Glandular hairs.* These bear at the apex a gland that usually produces a sticky substance, or a substance that is disagreeable to insects. (3) *Branched hairs.* (4) *Scales.* Broadly expanded, usually a single cell in thickness.

Trichomes may have the following functions: (1) Protection against rapid loss of water by transpiration. Long, closely packed, dry trichomes or scales retard the movement of air immediately above the transpiring leaf surface. (2) Trichomes may aid in draining water from the leaf. (3) Driving away insects: by bearing glands, by being sharp, or by forming a coat, outside the leaf, of structures which cannot be eaten. (4) Protection against other animals: by being harsh and dry, by producing disagreeable substances, etc. (5) Absorption. Some trichomes absorb water for the plant. Make a drawing of each the following types of trichomes: (1) Simple hairs of *Cucurbita maxima*, Calabaza, and *Nicotiana tabacum*, Tobacco. (2) Branched hairs of *Abroma.* [8] (3) Glandular hairs of *Nicotiana tabacum*, Tobacco, and *Lycopersicum esculentum*, Tomato. (4) Scales of *Aglaia iloilo*, Meliaceae, and *Heritiera littoralis*, Dungon, Sterculiaceae. [9]

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[7] Agave.
[8] Mullein.
[9] Elaeagnus.

3. *Stomata.* a. Typical stomata. Examine the stripped epidermis of *Musa textilis,* abaca, Musaceae,[10] for *stomata.*[11] These may be recognized as intercellular passages that perforate the epidermis and are bounded by two elliptical cells, termed *guard cells.* Increase in the turgor of the guard cells causes the stoma to open more widely. Try to find stomata that are open and others that are nearly closed. Do the guard cells contain chloroplasts? Do the other epidermal cells contain chloroplasts?

Transpiration is the evaporation of water from living plants. Water is transpired in the form of a vapor or gas. Water evaporated through the cuticle is called *cuticular transpiration;* that evaporated through the stomata is *stomatal transpiration.* In ordinary plants, the amount of water transpired through the stomata is very much greater than the amount transpired through the cuticle. The actual amount of water transpired, in a certain period of time, depends upon (1) the *transpiring power of the plant* (controlled by the extent of the leaf surface, the structure of the leaf, the number, distribution, and openness of the stomata, the amount of water in the leaf, etc.); and (2) the *external conditions surrounding the plant* (controlled by the temperature, moisture content of the air, and movement of the air, the intensity of sunshine, the amount of water in the soil, etc.).

For growth and manufacture of food, the plant organs must be turgid. Such turgidity depends upon the presence of plenty of water in the cells, so that the latter are swollen and enlarged with water. If water is lost by the leaves more rapidly than it is absorbed by the roots, the amount of water in the plant will be reduced, and loss of turgidity and wilting may follow. To remedy this, either the rate of absorption must be increased or the rate of transpiration must be decreased.

When a plant is transplanted many of the root hairs and fine root tips are destroyed. What effect would this have upon the rate of absorption of water by the plant? Why is it advisable to cut off some of the leaves before transplanting, to add water to the soil before and after transplanting, and to shade the plants for several days?

Draw a surface view of a stoma of *Musa textilis* that is open; show the guard cells and the other epidermal cells surrounding these. Make your drawing of the guard cells 5 cms. long. Examine in a similar way the stomata of *Maranta arundinacea,* arrowroot. Draw.

Study the stomata of *Maranta arundinacea*[12] (or of *Colocasia esculentum*) as seen in a cross-section of the leaf. Observe carefully the shape of the guard cells, and the unequal thickening of their walls. Where are the walls thinnest? The opening be-

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[10] Onion, beet, **Chrysanthemum, Coleus,** tomato, **Zebrina,** etc.
[11] Singular **stoma;** Gr. **stoma,** a mouth.
[12] Onion, beet, **Chrysanthemum, Coleus,** tomato, **Zebrina,** etc.

tween the guard cells is sometimes called the *stomatal pore.* Note the large intercellular space immediately beneath the stoma; this is the *respiratory-chamber.* This chamber is connected with other intercellular spaces within the leaf. Thus through the stomata all of the intercellular spaces of the leaf are connected with the external atmosphere. The stomata are often called the organs of *gaseous exchange* of the leaf. [13]

Make a drawing (5 cms. high) of the cross-section of a stoma of *Maranta arundinacea.* [14] Show accurately the thickening of the walls. Make a similar drawing of the stoma of *Musa textilis.*

b. *The Grass Stoma.* Examine the stripped epidermis of *Zea mays,* maize, Gramineae. [15] Note the dumb-bell-shaped guard cells, and the linear stomatal pore between them. The cell cavities of the guard cells are large at the ends and very narrow at the center. Changes in the volume of the enlarged end portions cause changes in the size of the pore. Do you find chloroplasts in the guard cells?Make a drawing of the surface view of a stoma, showing the guard cells and several of the other epidermal cells surrounding these. Make your drawing of the guard cells 5 cms. long.

c. *Opening and closing movement of a stoma.* Use stripped epidermis of *Maranta arundinacea, Rhoeo discolor,* or *Zebrina pendula.* Mount the material in water and examine under the microscope with bright light. Make a drawing (5 cms. long) of an open stoma. Then replace the water with a solution of glycerin, being careful not to move the slide. [16] Watch carefully for the change in the stoma. Make another drawing showing the stoma closed.

Then replace the glycerin solution with pure water and watch the stoma open again.

When the guard cells are swollen with water and in the light the stomatal pore opens. Glycerin has an attraction for water and draws water out of the guard cells. The guard cells have their walls thickened in such a way as to spring together and thus close the pore when water is withdrawn. When the leaf is transpiring water more rapidly than water is being replaced from the stem, the guard cells lose some of their water and tend to spring together,—thus closing the pore and diminishing the rate of trans-

[13] Carbon dioxide gas, which is used in the manufacture of food, enters the leaf through the stomata in the day time; oxygen gas, which is used in the process of respiration, enters the leaf through the stomata at night. Carbon dioxide, released in respiration, escapes from the stomata at night; oxygen, given off as a by-product in the process of food manufacture, escapes through the stomata during the day. Water vapor escapes through the stomata both during the day and during the night; but it escapes more rapidly during the day, because then the stomata are more widely opened and because the air is hotter and drier and the sun is shining.

[14] Onion, beet, **Chrysanthemum, Coleus,** tomato, **Zebrina,** etc.

[15] Wheat, barley, oats, Sorghum, etc.

[16] Glycerin solution may be drawn under the cover-glass by putting a drop of glycerin at one side of the cover-glass, and then carefully placing a piece of slightly moistened filter paper at the opposite side of the cover glass.

piration. The stoma tends to close with dryness. The glycerin has a similar effect, because it withdraws water from the guard cells. Explain the value to the plant of movable stomata.

The guard cells tend to lose water in darkness and therefore close. Stomata usually close at night, and in the afternoon on dry, warm days.

d. *Number of stomata per square millimeter of leaf surface.* Use an *eyepiece micrometer* ruled into squares. Calibrate this, by means of a *stage micrometer,* so as to determine the area enclosed by a square. Complete the following table:

Name of plant. [17]	Number of stomata per sq. millimeter.	
	Upper surface.	Lower surface.
Oryza sativa	....	....
Colocasia esculentum ...	....	....
Canangium odoratum ...	....	....
Cocos nucifera	....	....
Zea mays	....	....
Maranta arundinacea ...	....	....
Musa textilis	....	....

E. INTERNAL STRUCTURE OF THE LEAF

1. Cross section of the leaf of Coffea excelsa, coffee, Rubiaceae [18]

Examine a section under the microscope and locate a thin portion.

a. *Epidermis (epidermal tissue system).* Find the *epidermis.* This consists of a single layer of cells which covers both surfaces of the leaf. Do you find a layer of cuticle? Can you locate a stoma? What are the functions of the epidermis?

b. *Mesophyll (fundamental tissue system).* (1) *Palisade parenchyma.* This is the dark green layer of cells which is below the upper epidermis of the leaf. It is composed of elongated cells lying side by side, with their narrow upper ends placed at right angles to the upper epidermis. The protoplasm lining the walls of each palisade cell contains many chloroplasts. The chief function of the palisade parenchyma is to manufacture carbohydrate food (sugar and starch), from the carbon dioxide gas, absorbed through the stomata, and water, taken in by the roots of the plant. The energy comes from the light, which is absorbed by means of the chlorophyll. This process is *photosynthesis.* Oxygen gas is given off as a by-product. The food, manufactured by photosynthesis, dissolves in water and moves to various parts of the plant. The food is used in forming new protoplasm, in

[17] Wheat, oats, corn, alfalfa, cotton, potato, beet, beans, tobacco, pear, apple, peach, tomato, etc.

[18] Tomato, tobacco, bean, cotton, apple, etc.

releasing energy by the process of respiration, in forming cell-walls, etc., or it may accumulate in special parts or "storage" organs.

(2) *Spongy parenchyma.* This tissue is composed of light green cells that are more nearly spherical and are more loosely packed than those of the palisade parenchyma. The palisade parenchyma and the spongy parenchyma together constitute the *chlorenchyma* of the leaf. Note the large *intercellular air spaces,* particularly in the spongy parenchyma. What is the function of these?

c. *Veins (fibro-vascular tissue system).* Find a cross section of a large vein. Note that the xylem is placed above the phloem. Do you find a sclerenchyma ring or sheath around the bundle? Do you find a layer of colorless parenchyma around the bundle? The veins conduct water and mineral salts to the leaf, and carry prepared foods from the leaf to other parts of the plant.

Make a drawing (10 cms. wide) of a portion of the leaf. Show one complete vein and a few cells of each of the other tissues.

2. Cross-section of the leaf of Musa textilis, abaca, Musaceae [19]

Study this leaf carefully and compare its internal structure with that of *Coffea excelsa.* Note especially the layers of *colorless parenchyma* cells just beneath the upper epidermis. Why do these cells not appear useful as water storage tissue? Might they be of value by reducing the intensity of the light reaching the palisade parenchyma? Observe the very large intercellular spaces, forming canals. The veins of this leaf are like *I-girders,* [20] which run parallel to each other, and at right angles to the surface of the leaf. Explain why these are valuable in maintaining the form of the leaf. Make a drawing (10 cms. wide) showing your observations.

3. Cross-sections of several monocotyledonous leaves

Study cross sections of the leaves of (1) *Zea mays,* Maize, Corn; (2) *Oryza sativa,* Rice; and (3) *Saccharum officinarum,* Sugar Cane. Compare these leaves as to structure. Also compare these with the leaf of coffee. Make a drawing (8 cms. wide) of a portion of the cross section of each kind of leaf.

4. Cross section of the leaf of Eucalyptus tereticornis, Myrtaceae [21]

Examine a leaf that has not been sectioned. Note that it does not exhibit great differences between the upper and lower

[19] The leaf of **Zea mays** may be compared with the dicotyledonous leaf.
[20] An **I-girder** is a strong beam, shaped like the letter, I, for spanning an opening or carrying the weight of a floor, etc.
[21] **Eucalyptus** sp.

surfaces. Then study the cross section under the microscope. Note that there is a layer of palisade parenchyma near the lower epidermis as well as near the upper. The leaf hangs on the tree in such a way that both surfaces are exposed to intense light. Explain the development of the palisade parenchyma near each surface. Make a drawing (10 cms. wide) of a portion of the cross section including a *gland.*

5. *Sun and shade Leaves. Intsia bijuga, Ipil, Leguminosae. (Coffea, Theobroma, Mangifera, Nicotiana, or Rain Tree may be used)* [22]

Collect leaves that have been grown in strong sunlight and thus have been exposed to strong light and high transpiration rates. Also collect another set of leaves that have been grown in the shade. Compare the two sets of leaves as to color, nature of surface, size, and thickness. Do the leaves of one set feel softer than those of the other?

Examine on the same microscope slide two cross sections, one of a sun leaf and one of a shade leaf. Measure the thickness of each with a micrometer. Which one is thicker? Does the sun leaf or the shade leaf have the thicker cuticle? Do both leaves have the same number of layers of palisade parenchyma cells? Which kind of leaf has the palisade cells placed more closely together? Which kind has larger intercellular spaces between the spongy parenchyma cells? Which kind has the greater number of chloroplasts? Which leaf shows the greater development of sclerenchyma in the fibro-vascular bundles? Make a drawing of each leaf to show these differences.

What crops in the Philippines are usually shaded? Shading reduces the intensity of the sunlight, lowers the temperature, and retards the movement of the air. What is the effect of shade upon transpiration? Why is shading necessary for the crops just mentioned? If the air and soil are moist during the entire year, why is shade unnecessary for abaca? How are weeds injurious to crops?

6. *Accumulation of water in leaves. Furcraea gigantea, Mauritius Hemp, or Agave sisalana, Sisal Hemp* [23]

Examine a cross section of the leaf under the low and high powers of the microscope. How does this leaf differ in structure from that of the *Coffea* leaf? Make a drawing (10 cms. wide) showing these differences. Study in a similar way a cross section of the leaf of *Ananas sativus,* Pineapple, Bromeliaceae.

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[22] Apple, pear, peach, lettuce, etc.
[23] Agave.

F. FUNCTIONS OF LEAVES

1. *Transpiration*

(Exit of water vapor from the plant.)

Object: To demonstrate that a plant loses water by transpiration.

Equipment: A single-stemmed potted plant (such as papaya or tomato); a Ganong aluminum shell; a piece of rubber cloth; a balance.

Method: Place the pot in the Ganong aluminum shell. Cut a hole a little smaller than a stem in the center of the piece of rubber cloth, and make a cut with scissors from the margin of the cloth to the hole in the center. Place this rubber cloth around the stem and allow the cut edges of the rubber cloth to overlap; then seal the edges with liquid rubber cement. Clamp the rubber cloth tightly around the aluminum shell by means of a metal band.[24]

Weigh the pot and plant, thus prepared, on the balance. This weighing should be made at about seven o'clock in the morning. Record the exact time and weight. Then place the enclosed potted plant out-of-doors in sunlight. Re-weigh the enclosed pot at about five p. m., again recording the exact time and weight. At about seven o'clock on the following morning, the enclosed potted plant should be weighed a third time.

Since no water can escape through the aluminum shell or through the rubber cloth, any loss in weight of the enclosed potted plant must be due to evaporation of water from the plant surfaces; that is, such loss in weight must be due to transpiration. Record your results in the form of a table. Now determine the leaf area of the plant. This may be done by removing the leaves from the plant and tracing them upon the cross section paper and counting the enclosed areas. Obtain in this way the total leaf area of the plant. The amount of water transpired should be divided by the leaf area expressed in square meters. This will give the amount of water transpired for each square meter of leaf surface during the periods of the experiment. Then divide this value by the number of hours during which the plant transpired; the value obtained will show the average hourly rate of transpiration per square meter of leaf area. Compare the average hourly rate of transpiration during the hours of daylight with the rate during the night.

2. *Photosynthesis*

a. *Object:* To demonstrate that starch accumulates in green leaves in sunlight.

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[24] If the aluminum shell and rubber cloth are not available, the plant may be grown in an "evaporated milk can" and the surface of the soil may be covered melted paraffin.

Equipment: A potted plant that has been exposed to sunlight; a small Ganong light screen; a dark chamber; alcohol; iodine solution;[25] a beaker of water and flame for boiling the latter; a test-tube; a flat white dish.

Method: Remove a leaf from the plant. Place the leaf in boiling water for a few seconds; place it in a test-tube containing alcohol until the chorophyll has been removed; then place it in iodine solution in a white dish. Note the blue color due to the starch in the leaf.

Place the plant in the dark chamber until all the starch has disappeared from its leaves; this will require one or two days, or perhaps longer. To be certain that the starch has disappeared, test a leaf from the plant with iodine solution, as before; there should be no indication of a blue color. When the starch has disappeared, cover a leaf with the simple Ganong light screen. which allows light to reach part of the leaf area and prevents it from reaching other parts of the leaf area. Expose the plant to bright sunlight for five hours. Then test this leaf with iodine solution and determine the regions of the leaf which contain starch. Explain the result of this experiment.

b. *Object:* To show that starch is usually formed in the chloroplasts in green leaves.

Equipment: A plant which has been in darkness long enough for the starch to have disappeared from its leaves; razor; concentrated chloral hydrate solution; iodine solution; water; slide and cover glass; microscope.

Method: Cut sections from a leaf; place the sections in the chloral hydrate solution to remove the chlorophyll and render them transparent; mount the sections in water; apply iodine solution, and examine the sections under the microscope. Then place the plant in bright sunlight for a period of about five hours; cut sections from a leaf; treat these with chloral hydrate; mount in water; apply iodine solution, and examine under the microscope. Note the appearance and location of starch. Discuss what this experiment demonstrates.

3. Respiration

This process occurs in all living cells; but it is convenient to study it in connection with the leaf and to contrast it with the process of photosynthesis.

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[25] Formula for iodine solution: iodine 1 gram, potassium iodide 5 grams, water 1 liter. The potassium iodide is added to increase the solubility of the iodine in water.

Object: To demostrate that carbon dioxide gas is released by plants.

Equipment: Two glass cylinders, each about five cms. in diameter and 10 cms. high with tight-fitting stoppers; two circular diaphragms of wire netting; two pieces of filter paper; lime-water; twenty germinating rice seeds; water.

Method: Soak the rice seeds in water for 24 hours. Fill each cylinder one-third full with lime-water. Suspend the wire netting diaphragm at a height of two cms. above the lime-water. Place the germinating seeds on wet filter paper on the netting in one cylinder; use the other cylinder, without seeds, as a *control.* Tightly stopper both cylinders, and place them in the dark. Whitening of the lime-water, due to the formation of calcium carbonate, will show the presence of carbon dioxide gas. Observe the appearance of the lime-water in the two cylinders for several days. Note that the lime-water in the cylinder containing germinating seeds whitens, thus proving the presence of carbon dioxide gas; this gas is released by the plants in the process of respiration. Also, note that the lime-water in the *control* cylinder does not whiten, since the amount of carbon dioxide normally present in the air is insufficient to produce an effect upon lime-water.

In the process of respiration, oxygen gas is absorbed from the air by the plants, and carbon dioxide gas is given off to the air. In addition to carbon dioxide, water is given off in the process of respiration.

In the process of respiration energy is released; by means of this energy the plant is able to grow and to carry on other processes that involve *work.*

In many respects the process of respiration is the reverse of the process of photosynthesis. The differences between the two processes are brought out by the following table:

Respiration.	*Photosynthesis.*
1. Takes place in all active cells, in all plants and animals.	1. Takes place only in the chloroplasts of green plants.
2. Occurs in both light and darkness.	2. Occurs only in light.
3. Absorbs oxygen.	3. Releases oxygen.
4. Releases carbon dioxide.	4. Absorbs carbon dioxide.
5. Releases water.	5. Absorbs water.
6. Decomposes carbohydrate food.	6. Constructs carbohydrate food.
7. Releases energy.	7. Stores energy of sunlight.

4. Functions of leaf tissues

Complete the following table so as to show the chief functions of each of the tissues of a typical leaf, such as that of *Coffea excelsa.*

Tissue.	Function.
Epidermis	. . . .
Fibro-vascular bundle	. . . .
Palisade parenchyma	. . . .
Spongy parenchyma	. . . .
Intercellular spaces	. . . .
Stomata	. . . .

G. LEAVES WHICH HAVE ECONOMIC VALUE

Complete the following table. Also add other examples.

Common name of plant.	Scientific name of plant.	Annual value to P. I.	Use to man.
Grass, Barit, Zacate	*Leersia hexandra*	. . . .	. . . .
Maguey	*Agave cantula*	. . . .	. . . .
Sisal Hemp	*Agave sisalana*	. . . .	. . . .
Mauritius Hemp .	*Furcraea gigantea*	. . . .	. . . .
Nipa	*Nipa fruticans*	. . . .	. . . .
Buri	*Corypha elata*	. . . .	. . . .
Mulberry	*Morus alba*	. . . .	. . . .
Garlic	*Allium sativum*	. . . .	. . . .
Onion	*Allium cepa*	. . . .	. . . .
Mustard	*Brassica juncea*	. . . .	. . . .
Pechay	*Brassica pekinensis*	. . . .	. . . .
Tobacco	*Nicotiana tobacum*	. . . .	. . . .
Betel Pepper . . .	*Piper betle*	. . . .	. . . .
Abacá	*Musa textilis*	. . . .	. . . .
Cogon	*Imperata cylindrica var. Koenigii*	. . . .	. . . .
Pineapple	*Ananas sativus*	. . . .	. . . .
Rain tree	*Enterolobium saman*	. . . .	. . . .
Cabbage	*Brassica oleracea*	. . . .	. . . .
Lettuce	*Lactuca sativa*	. . . .	. . . .
Spinach	*Spinacea oleracea*	. . . .	. . . .
Celery	*Apium graveolens*	. . . .	. . . .

H. METAMORPHOSED LEAVES

A metamorphosed leaf is one that is changed in structure, and which performs some function that is not performed by a typical leaf, or which performs the typical leaf functions under unusual conditions.

1. Metamorphosed blades or whole leaves.

a. *Tendrils.* Examine the leaf of *Pisum sativum*, Pea, Leguminosae. Note that the leaf is compound, ending in a branched *tendril*, which enables the plant to climb. Tendrils are slender sensitive organs that coil spirally and serve as a means of attachment to a supporting body. Also note that the pair of stipules at the base of the petiole are large and leaflike. Draw.

b. *Spines.*[26] Examine the spines of *Ananas sativus*, Pineapple, Bromeliaceae. Draw one variety that has both apical and marginal spines, and another that has only apical spines. Draw the apical spines of *Furcraea gigantea*, Mauritius Hemp.

c. *Water reserve.* Make a drawing of the whole leaf of *Agave* or *Furcraea*, and another drawing of the cross section of the leaf.

d. *Hinge.* Examine the pinna of *Cocos nucifera*, Coconut, Palmae. Observe the changes that take place in the halves of the pinna as the leaf becomes dry. What is the advantage of this? Study under the microscope a cross section of the leaf. Draw the hinges and explain their mechanism.

2. Metamorphosed petioles.

As a photosynthetic organ. Draw the modified petiole of *Acacia sp.*

3. Metamorphosed leaf bases.

a. *Sheath.*[27] Examine the leaf of *Oryza sativa*, Rice, Gramineae, or of *Zea mays*, Maize, Gramineae. Note that the leaf base is modified as a sheath that protects the growing region at the base of the internode. Draw.

b. *Tendril.* Draw a leaf of *Smilax bracteata*,[28] Obat, Liliaceae, showing the *tendrils*.

c. *Spines.* Draw the leaf of *Acacia farnesiana*,[29] Aroma, Leguminosae, showing stipules which are modified to form spines. How can you distinguish a stem spine from a leaf spine?

d. *Food reserve.* Study a bulb of *Allium cepa*, onion, Liliaceae. Cut the bulb in halves, lengthwise. Note that most of the bulb consists of thickened scales, which are leaf bases, filled with accumulated food materials. Find the solid, stem portion of the bulb. Make a drawing of the longitudinal section.

e. *False trunk.* Examine both cross and longitudinal sections of the trunk of *Musa textilis*, Abacá, and of *Musa sapientum*, Banana. You will observe that the trunk is composed almost entirely of overlapping leaf bases. Compare this with the case of the sheathing leaf bases of *Oryza sativa* and other grasses. Where is the main stem of the banana? When does the true erect stem appear? Make a drawing of the cross section of a banana stem.

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[26] **Agave**; barberry.
[27] Wheat, oats, corn, barley, sorghum, etc.
[28] Other species of Smilax.
[29] **Euphorbia** sp.

I. SUMMARY OF PLANT TISSUES

1. Complete the following outline by giving the principal functions of each of the tissues named.

1. *Epidermal tissue system.*
    - Dermatogen on root and stem tips.
    - Epidermis on stem and leaf.
    - Hair layer on young roots.
2. *Fundamental tissue system.*
    - Periblem region of root and stem tips.
    - Mesophyll of leaf; palisade parenchyma and spongy parenchyma.
    - Green parenchyma of young stem.
    - Cortex of bark and of young root.
3. *Fibro-vascular tissue system.*
    - Plerome region of root and stem tips.
    - Stele of root and stem.
        - a. Phloem.
        - b. Cambium.
        - c. Xylem.
        - d. Pith.
    - Veins of leaves.
        - a. Phloem.
        - b. Xylem.

2. Complete as fully as possible the following table by inserting where possible, the special tissue in each of the organs of the plant.

Function.	Tissue concerned.		
	Root.	Stem.	Leaf.
Protection	....	....	....
Photosynthesis	....	....	....
Absorption of water and salts	....	....	....
Absorption of gases ..	....	....	....
Transpiration	....	....	....
Conduction of water ..	....	....	....
Conduction of food ..	....	....	....
Growth	....	....	....
Reproduction	....	....	....
Support	....	....	....
Storage	....	....	....
Respiration	....	....	....

VII. THE FLOWER

The function of the flower is to produce seeds, which are the reproductive structures that develop into new individuals like the parent plant, that is, to produce plants of the next generation. In structure, the flower is composed of specially modified leaves, called *floral leaves,* and the stem apex which bears them.[1]

A. THE ARRANGEMENT OF FLOWERS ON THE STEM: INFLORESCENCE

1. Staminate flower cluster of Papaya, Carica papaya, Caricaceae[2]

Is the group of staminate flowers borne in the axil of a leaf (*axillary*) or is it at the end of the main stem (*terminal*)? Does the flower cluster continue growing and producing new flowers for a time, so that the lower flowers are older and the upper ones younger (*racemose or indeterminate*)? Or does a terminal flower end the principal stem of the cluster, so that no further growth of the main stem is possible (*cymose or determinate*). The main stalk that bears the cluster of flowers is the *peduncle,* and the small stalks bearing the individual flowers are called *pedicels.* Do the individual flowers possess *pedicels* or are they *sessile?* Are the flowers borne along a simple undivided axis (*spike*) or are they borne on an axis that is rather irregularly divided into branches (*panicle*)? Draw.

2. Pistillate flower of Papaya[2]

Are the pistillate flowers axillary or terminal? Are they *solitary* or grouped in clusters? If they are grouped in clusters, is the cluster (1) racemose or indeterminate, or is it (2) cymose or determinate? Are the flowers sessile on an undivided axis (*spike*) or are they pedicelled on such an axis (*raceme*)? Draw.

3. Various types of inflorescence.

Collect as many kinds of flower clusters as possible. With aid from the instructor classify these inflorescences according to the following types: spike, raceme, panicle, umbel, head, corymb, cyme, fascicle, catkin, spadix. Draw.

B. THE GYNAECIUM: COMPOSED OF CARPELS

1. Pistillate flower of Papaya[3]

Examine the large central organ of the flower, the *pistil.* The upper portion of this is composed of five lobed *stigmas,* which receive the pollen. The enlarged lower portion of the pistil is

[1] It will be seen when the reproductive life-history of the plant is studied that this brief explanation of the flower is not complete; but it is sufficiently general for the purposes of our present study.
[2] Flower of tomato, tobacco, a fruit tree, cotton, etc.
[3] Flower of tomato, tobacco, a fruit tree, cotton, etc.

the *ovary*. Are the stigmas raised from the ovary on a stalk (*style*), or are they sessile? Make a cross section of the ovary. Does the ovary contain one or several compartments or cells? Find the small round bodies, the *ovules*. [4] Are the ovules attached to the walls of the ovary (*parietal*)? The surfaces on which the ovules are attached are the *placentae;* in this flower the placentae are parietal (on the walls).

Make a drawing (5 cms. long) of the pistil. Also make a drawing of the side view of a pistil that has been cut in halves longitudinally. Make a drawing (5 cms. long) of the ovary which has been cut in halves transversely, showing the *placentation* and the number of cells of the ovary.

The pistil is composed of parts called *carpels,* which are modified leaves. In the pistil the carpels are composed of modified leaves which have folded with the upper surface inward. The *placentae,* upon which the ovules are borne, are usually the infolded edges of the carpels.

The fact that there are five stigmas and that the ovary has five lobes indicates that this pistil is composed of five united *carpels.* The carpels collectively form the *gynaecium.*

Remove several ovules and examine these with the hand lens and low power of the microscope. Make a drawing (1 cm. *long*) showing an ovule and its attachment to the placenta.

2. *Various types of gynaecia.*

Collect a number of flowers having different sorts of pistils. Find pistils which are *simple,* that is, composed of carpels which are free and each of which gives rise to a separate fruit; and pistils which are *compound,* that is, composed of several carpels united. Cut transverse sections of the ovaries and make drawings showing the number of cells and the placentation.

C. THE ANDROECIUM: COMPOSED OF STAMENS

1. *The staminate flower of Papaya* [5]

Note that in the center of the male flower there is an undeveloped pistil. Next to this are the *stamens,* each of which consists of a stalk (*filament*) and a terminal expanded portion (*anther*). Note that the anthers shed a fine yellow powder, the *pollen.* This is produced in cavities called *pollen sacs.* [6] The manner in which the pollen sacs open is called the *dehiscence.* Are the stamens introrse, turned inward toward the pistil, or are they *extrorse,* turned outward? How many stamens do you find? Make a drawing (4 cms. *long*) of a single stamen. With the aid of the hand lens draw (2 cms. *long*) an anther to show the dehiscence. Collectively the stamens form the *androecium.*

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[4] Morphologically, the **ovule** is a plant-member called a sporangium, which in origin and position is neither **leaf** nor **stem.**

[5] See note on preceding exercise.

[6] The **pollen-sac,** like the ovule, is a distinct plant-member called a **sporangium.** Morphologically, the plant may be divided into **root, stem, leaf,** and **sporangium.**

2. Structure and germination of pollen.

Examine under the microscope some of the pollen of papaya; make this examination first with dry pollen and then with pollen mounted in a 10 per cent cane sugar solution. Make a drawing (5 cms. in diameter) to show the structure of the walls.

Repeat this exercise, using pollen of *Cucurbita maxima, Phaseolus lunatus, Zea mays,* and *Oryza sativa.* Describe the differences which you observe in structure and abundance. How may these differences be related to the method of pollen transportation?

Germinate pollen of each kind in a solution containing five or ten per cent of cane sugar and one per cent of *agar-agar.* Study the growth of the *pollen tube* and make a drawing of a germinated pollen grain of each kind.

3. Essential parts of the flower.

The really essential parts of the flower are the gynaecium and the androecium. Pollen is transferred from the stamens to the stigmas, this process being called pollination. Each pollen grain then starts to grow (*germinate*) by producing a tubular structure (*pollen tube*) that grows through the stigma to an ovule. The male sexual nucleus (*sperm nucleus*) of the pollen grain then unites with the female sexual nucleus (*egg nucleus*) of the *embryo sac* (in the ovule), this union being called *fertilization.* The *fertilized egg* or *zygote* then develops into the *embryo,* which you have already studied in the seed.

4. Different types of androecia.

Collect flowers having different forms of stamens. Make drawings of these to show the types of filaments, anthers, and dehiscence.

D. PERIANTH: CALYX AND COROLLA

Pistillate flower of Papaya [7]

The essential parts of the flower (*androecium and gynaecium*) are usually surrounded by two circles or *whorls* of floral leaves that have a protective function. The outer of these whorls forms the calyx, and the inner the *corolla.* The calyx and corolla together constitute the *perianth.* Examine the calyx. Of how many parts, *sepals,* is it composed? Is the calyx *gamosepalous,* with sepals united, or is it *polysepalous,* with sepals free from each other? How many lobes does the calyx have? Study now the *corolla.* How does the corolla differ in color and appearance from the calyx? Of how many parts (*petals*) is the corolla composed? Are these parts alternate with the parts of the calyx, or opposite them? Is the corolla *gamopetalous* (*sympetalous*), having the parts united, or *polypetalous* (*choripetalous*), having the petals free from each other? Make a drawing (5 cms. *long*) to show the corolla, and another to show the calyx. Discuss the functions of the calyx and of the corolla.

[7] See note on preceding exercise.

E. PARTS OF THE FLOWER IN RELATION TO ONE ANOTHER [8]

1. Cut the flower longitudinally. Make a drawing (5 cms. long) of the half flower as seen from the cut side. In this drawing show the relative positions and heights of the calyx, corolla, and pistil. The apex of the stem which bears the parts of the flower is the *receptacle.*

2. *Various relations of receptacle, calyx, corolla, stamens, and carpels, as represented by longitudinal sections of flowers.* Collect a number of types of flowers, cut longitudinal or vertical sections and determine the relative positions of the parts of the flowers. (1) Find flowers in which the sepals, petals, stamens, and carpels all stand separate upon a simple receptacle. This is the common type in which the ovary is termed *superior,* and the flower *hypogynous* (meaning under the pistil). (2) Find other flowers in which the sepals, petals, and stamens stand upon the top of the ovary. In this case, the ovary is termed *inferior* and the flower is termed *epigynous* (meaning upon the pistil). (3) Find other flowers in which the calyx and corolla form one structure upon which the stamens stand. A flower of this type is called *perigynous* (meaning around the pistil). Make drawings to show these principal types. Various modifications of these may also be found.

3. Make a *floral diagram* to show the relative positions of the sepals, petals, and cells of the ovary. Place the diagram on the page in such a way that the transverse section of the axis of the inflorescence (indicated by a dot) stands above, while that of the bract (if present) stands below. Represent the ovary in cross-section, showing the placentation. Indicate the place where the stamens should occur by a dotted circle around the ovary. Represent the cross-sections of the petals and sepals by arcs of a circle, properly placed.

4. *Various arrangements of floral parts as represented by cross-sections of flowers.* Collect several types of flowers and make diagrams to show the relative positions of the parts as seen in cross-section.

F. THE FLOWER OF PACHYRRHIZUS EROSUS, SINCAMAS, LEGUMINOSAE [9]

1. *Inflorescence.* Study the arrangement of the flowers on the stem. Note that they are borne in clusters in the axils of leaves. Does the cluster continue to grow in the main axis and continue to produce new flowers for a time? Are the lower flowers of the cluster older, and the upper flowers younger? What is the name of an inflorescence of this kind? Draw.

2. *Gynaecium.* Remove the outer parts of the flower and study the pistil. Make a drawing (6 cms. long) of the pistil, as seen from the side. Label *ovary, style,* and *stigma.* Now split the

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[8] See notes on preceding exercises.
[9] Beans or peas.

ovary longitudinally. How many ovules do you find? How are they borne? This ovary has how many cells? This is a simple pistil, composed of a single carpel. Make a longitudinal drawing (6 cms. long) of the ovary.

3. *Androecium.* In another flower examine the stamens surrounding the pistil. How many stamens do you find? Note that the stamens are united by their filaments into two sets. They are said to be *diadelphous* (meaning two brotherhoods). Note that all but one cohere in a tube around the pistil.

Make a drawing (8 cms. long) of the stamens, showing the nine united stamens and the single *free* stamen. Label filaments and anthers.

4. *Perianth: Calyx and corolla.* Examine the calyx. Is the calyx composed of separate sepals (*polysepalous*) or are the sepals united into a tubular structure (*gamosepalous*)? Make a drawing (3 cms. long) of the calyx. Study now the corolla. What is its color? Is the corolla *polypetalous* or *gamopetalous?* This corolla is said to be *papilionaceous* or butterfly-shaped. Note that there is an upper and outer larger petal, and that there are four others in opposite pairs. Make a drawing (8 cms. wide) of the flower from the end, showing the corolla.

5. *Floral diagram.* Make a cross-section diagram (8 cms. in diameter) showing the numbers and relative positions of each of the parts of the flower.

G. THE GRASS FLOWER

Oryza sativa, Rice, Gramineae [10]

Examine a flower cluster of rice. This type of inflorescence is a *compound raceme* or *panicle.* Draw (X2) a small portion of the panicle. The individual inflorescences of grasses are called *spikelets.* In the case of rice, each spikelet bears only a single flower. Are the spikelets jointed on the panicle branches? Examine a single spikelet. The spikelet contains four convex bracts, the outermost two of which are called *empty glumes.* These are small dry scales. Above these empty glumes is a third glume, usually called the *palea inferior.* The palea inferior is larger and tougher than the empty glumes. Its apex may bear a stiff bristle or awn. How many veins or nerves does the palea inferior have? What is their direction? Above the palea inferior observe the *palea superior,* which encloses the essential parts of the flower. Is the palea superior exactly like the palea inferior in size and appearance? Is the number of nerves the same? Look carefully above the palea superior for two small structures called *lodicules,* the swelling of which causes the flower to open. Make a drawing (5 cms. *long*) of the spikelet as seen from the side.

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[10] Wheat, oats, rye, barley, corn, etc.

Within the palea superior look for the *stamens.* Each stamen consists of a thread-like filament and an anther which contains pollen. How many stamens are there? How is the filament attached to the anther? Make a drawing (5 cms. long) of a stamen. All the stamens taken together form the *androecium.* Above the stamens, or at the center of the flower is the *pistil.* The pistil consists of a swollen portion called the *ovary* and two feather-like *stigmas.* The pistil constitutes the gynaecium. Make a drawing (3 cms. long) of the pistil.

H. FLOWERS WHICH HAVE ECONOMIC VALUE

Look up the necessary information to fill out the following table:

Common name of plant.	Scientific name of plant.	Use to man.	Annual value in the P. I.
Caturay	*Sesbania grandiflora*	....	....
Champaca	*Michelia champaca*	....	....
Rose	*Rosa sp.*	....	....
Squash	*Cucurbita maxima*	....	....
Ilang-ilang	*Canangium odoratum*	....	....
Banana	*Musa sapientum*	....	....

I. AN EXERCISE IN CROSS-POLLINATION

Sex of Papaya

1. Find a papaya plant that bears staminate (male) flowers, but that bears in addition some pistillate (female) or perfect flowers (flowers having both stamens and pistil). Pollinate a pistillate (female) or perfect flower using pollen for this from a staminate (male) tree. When the fruit is ripe, collect the seed, plant it, and note the sex of the plants grown from the seed. Take care to exclude other pollen from the flower treated. If the flower is perfect, remove the stamens before they mature. Tie a paper bag over the pistillate (female) or perfect flower that is to be pollinated. This bag should be put over the flower several days before the flower opens and should not be removed until the fruit has begun to grow. Use pollen from a flower that has just opened. You should be able to see an abundant quantity of pollen on the stamens you use.

2. Get pollen from a plant that is staminate but that bears some pistillate or perfect flowers. Apply this pollen to a flower on a strictly pistillate (female) tree. Take care to exclude all other pollen from the flower treated. Collect the seed produced by the flower so treated, plant the seed, and note the sex of the resulting crop.

VIII. THE FRUIT.

The *fruit* is a structure which appears after the flower and contains one or more seeds. The fruit develops from the ovary, or from the ovary and some additional parts, as a result of fertilization. The additional parts that most frequently develop into a part of the fruit are the calyx and the receptacle. The walls of the ovary become the walls, or *pericarp,* of the fruit; the ovules become the *seeds.* In function, the fruit is concerned with the development and distribution of the seeds.

A. STRUCTURE OF FRUITS

1. Fruits may be *simple,* those resulting from a single ovary, as those of the bean. Or they may be *aggregate,* when several or many carpels of a single flower develop into a single mass, as in *Anona* (Anonas, Ates).[1] Furthermore, fruits may be *collective* or *multiple,* when the carpels of a number of flowers develop together in one mass, as in the *Ananas sativus* (Pineapple) or *Artocarpus integrifolia,* (Jak-fruit, Lanca, Nanca).

2. The wall of the fruit is called the *pericarp* (from Gr. *peri,* around; *karpos,* fruit). As the fruit ripens the walls of the ovary develop into the pericarp. When the pericarp is composed of several distinct layers, the innermost layer is called the *endocarp,* the middle layer the *mesocarp,* and the outermost layer the *exocarp.*

3. Fruits that open to allow the escape of the seeds are said to be *dehiscent,* while those which remain closed are called *indehiscent.* The seeds of indehiscent fruits are liberated in other ways.

4. As to *texture, fruits* may be classified as (1) *fleshy,* when the walls of the ovary become soft and juicy, as is true of the banana, chico, and papaya,[2] and (2) *dry,* when the pericarp becomes woody or paper-like, as in the pod of the bean. Also, the outer part of some fruits becomes fleshy, while the inner part becomes hard and dry, as in the mango and duhat.[3]

B. PARTS OF THE FLOWER THAT REMAIN IN THE FRUIT

Make a drawing of each of the following fruits and label your drawings so as to show from what parts of the flower each part of the fruit has developed. a. *Phaseolus lunatus,* Lima Bean, or *Vigna sinensis,* Cowpea, Leguminosae. b. *Ananas sativus,* Pineapple, Bromeliaceae. c. *Hibiscus sabdariffa,* Rozelle, Malvaceae. d. *Lansium domesticum,* Lanson,[4] Meliaceae. e. *Lycopersicum esculentum,* Tomato, Solanaceae.

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[1] Mulberry.
[2] Grape, cranberry, blueberry.
[3] Peach, plum, cherry.
[4] Blackberry. Add the **pome** type, in apple and pear.

C. CLASSIFICATION OF FRUITS

Study and draw one fruit of each of the following types.

a. *Nut. Cocos, Canarium, or Quercus.* [5] A dry and indehiscent fruit, commonly one-celled and one-seeded, with a hard thick wall.

b. *Caryopsis or grain. Oryza or Zea.*[6] A fruit with the seed adhering to the thin pericarp throughout, so that both are united nito a single structure.

c. *Achene. Cyperus, Blumea, or Synedrella.*[7] A small, dry indehiscent, one-seeded fruit, often seedlike in appearance.

d. *Follicle.* [8] *Connarus neurocalyx,* Sandaleno, and *Rourea erecta,* Camagsa,—both of Connaraceae. A fruit composed of a simple carpel, which dehisces down one side only.

e. *Legume or pod.* Bean, pea, etc., Leguminosae. A dry fruit composed of one carpel, which dehisces along two sides.

f. *Loment. Peanut or Desmodium.* Similar to a legume, but constricted between the seeds. It breaks up crosswise into distinct joints.

g. *Capsule. Nicotiana, Torenia, Amaranthus.* A dry dehiscent fruit of a compound pistil, opening by longitudinal cracks.

h. *Pyxidium. Portulaca, Plantago.* Similar to a capsule, but opening by a lid.

i. *Drupe or stone-fruit. Mangifera, Eugenia* (duhat).[9] A fruit in which the outer part becomes soft and fleshy, while the inner part becomes soft.

j. *Berry.* [10] Papaya, tomato, egg plant, chico, lanson, orange. Soft and fleshy throughout.

D. DISPERSAL OF FRUITS AND SEEDS

Collect specimens to illustrate the different ways in which fruits and seeds are scattered. Make drawings and explain how each type is distributed. Study the following types:

1. *Dispersal by propulsion.*
   a. By violent dehiscence.[11] *Bauhinia, Ricinus,* and *Oxalis.*
   b. By mechanical impact.[12] Many capsules and pods.
   c. By awns:[13] changes in moisture causing movement along ground. Many grasses.
2. *Dispersal by water. Cocos.*

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[5] Walnut, butter-nut, hickory, pecan, etc.
[6] Wheat, oats, corn, rye, barley, Sorghum, etc.
[7] Strawberry, butter-cup.
[8] Peony, larkspur, milk-weed.
[9] Cherry, plum, peach.
[10] Grape. cranberry, blueberry, banana.
[11] **Impatiens, Pelargonium, Hura.**
[12] **Oenothera, Pedicularis.**
[13] **Stipa, Avena, Aristida, Erodium.**

3. *Dispersal by wind.*

a. Whole plant rolls. *Tumbleweeds.*
b. Inflorescence flies. *Tilia.*
c. Inflorescence rolls. *Spinifex.*
d. Fruit flies.
By wing.[14] *Dipterocarpus, Pterocarpus, Ailanthus.*
By hairs, like a parachute. *Compositae.*
e. Seed flies.
By wing.[15] *Dioscorea, Pterospermum, Zanonia.*
By hairs, like parachute. *Asclepiadaceae, Ceiba.*
By light weight. *Orchidaceae.*

4. *Dispersal by animals.*

a. By adhering with hooked appendages. *Burs.*
b. By being eaten.

Fleshy portion eaten; seeds discarded.
Fleshy portion and seeds swallowed; seeds passing undigested through alimentary canal. *Morus.*

E. FRUITS WHICH HAVE ECONOMIC VALUE

Complete the following tables as far as you are able.

1. Garden fruits or vegetables.

Common name of plant.	Scientific name of plant.	Classification of fruits.	Uses to man.	Annual value to P. I.
Egg plant ..	*Solanum melongena*	....	.....	....
Tomato	*Lycopersicum esculentum*	....	.....	....
Mungos	*Phaseolus radiatus*.	....	.....	....
Okra	*Abelmoschus esculentus*	....	.....	....
Roselle......	*Hibiscus sabdariffa*	....	.....	....
Squash	*Cucurbita maxima* .	....	.....	....
Pepper, Sileng-bilog .	*Capsicum annuum, var. grossum* ...	....	.....	....

[14] Acer, Ptelea, Fraxinus.
[15] Catalpa.

2. Fruits in common use of the word.

Common name of plant.	Scientific name of plant.	Classification of fruits.	Uses to man.	Annual value to P. I.
Camagon, Mabolo . . .	*Diospyros discolor.*	. . . .	. . . . .	. . . .
Ates, sugar apple, sweet sop . .	*Anonas squamosa. .*	. . . .	. . . . .	. . . .
Bread fruit, rimas, camansi	*Artocarpus communis*	. . . .	. . . . .	. . . .
Banana	*Musa sapientum* . .	. . . .	. . . . .	. . . .
Orange (narangita or sintones . .	*Citrus nobilis*	. . . .	. . . . .	. . . .
Calamansi . .	*Citrus mitis*	. . . .	. . . . .	. . . .
Dayap, limon.	*Citrus lima*	. . . .	. . . . .	. . . .
Lansone	*Lansium domesticum*	. . . .	. . . . .	. . . .
Papaya	*Carica papaya*	. . . .	. . . . .	. . . .
Jak-fruit (Lanca, nanca)	*Artocarpus integrifolia*	. . . .	. . . . .	. . . .
Mango	*Mangifera indica. .*	. . . .	. . . . .	. . . .
Citron	*Citrus medica*	. . . .	. . . . .	. . . .
Chico	*Achras sapota*	. . . .	. . . . .	. . . .
Pineapple . . .	*Ananas sativus* . . .	. . . .	. . . . .	. . . .
Pomelo, lucban, suha . .	*Citrus decumana* . .	. . . .	. . . . .	. . . .
Duhat	*Eugenia jambolana*	. . . .	. . . . .	. . . .
Avocado	*Persea americana. .*	. . . .	. . . . .	. . . .

3. Grains or cereals.

Common name of plant.	Scientific name of plant.	Classification of fruits.	Uses to man.	Annual value to P. I.
Rice	*Oryza sativa*	. . . .	. . . . .	. . . .
Maize	*Zea mays*	. . . .	. . . . .	. . . .
Millet				. . . .

4. Miscellaneous fruits.

Common name of plant.	Scientific name of plant.	Classification of fruits.	Uses to man.	Annual value to P. I.
Cotton	*Gossypium hirsutum*	....	.....	....
Coconut	*Cocos nucifera*	....	.....	....
Coffee	*Coffea arabica* ...	....	.....	....
Cacao	*Theobroma cacao*..	....	.....	....
Pepper (Chile) ...	*Capsicum frutescens*	....	.....	....
Poppy	*Papaver somniferum*	....	.....	....
Areca Nut ..	*Areca catechu*	....	.....	....
Pili Nut	*Canarium sp.*	....	.....	....
Peanut (Mani)	*Arachis hypogaea*..	....	.....	....
Castor Bean .	*Ricinus communis*..	....	.....	....

PART II. SYSTEMATIC BOTANY

Systematic botany is that branch of botany which deals with the description and systematic arrangement of plants into groups in accordance with their relationships. The basis for the arrangement of plants according to their relationships is furnished by the theory that all organisms existing at the present time have developed by gradual modification from previously existing organisms. This division of botany dealing with the classification of plants is frequently given the special name of *taxonomic botany.* Before taking up the classification of *true* plants, we shall study certain *primitive* organisms which are believed to be similar to the *ancestors* of true plants. Since it is difficult to classify these primitive living things, they are frequently studied in courses in zoology as well as in botany.

I. PRIMITIVE ORGANISMS

A. SCHIZOPHYTES

The *Schizophytes* are very primitive organisms which are believed to be the ancestors of the major kindoms of plants and animals as well as of several minor kindoms of living things. Schizophytes are one-celled, or are composed of filaments or masses of physiologically independent cells. They are without nuclei that are stained by the substances which stain the nuclei of plants and animals. Schizophytes contain no plastids. Either they contain no chlorophyll or their chlorophyll is masked by another pigment. Schizophytes *reproduce* principally by *fission;* that is, the organism divides into two parts, each of which then becomes a complete organism. Some Schizophytes reproduce also by *spores,* which are special one-celled reproductive structures, each of which is capable of growth into a new individual. Schizophytes never reproduce *sexually;* that is, they never reproduce by a process requiring the union of two sex cells.

Schizophytes may be classified in three groups: (1) Thiobacteria, (2) Bacteria, and (3) Cyanophyceae. The Thiobacteria are minute, generally filamentous organisms, which often inhabit sulphur springs; their cells contain sulphur inclusions and are never green in color, but may be reddish or violet, because of a pigment called bacterio-purpurin. Bacteria are very minute; they are usually colorless, and never contain chlorophyll. The Cyanophyceae organisms are generally larger than the individuals of the other two groups, and possess chlorophyll, but the green color of the chlorophyll is masked by the presence of a blue pigment.

1. *Bacteria*

Bacteria are extremely minute Schizophytes that are only visible with the highest power of the microscope. Some bacteria decompose organic matter; others cause fermentation; others fix atmospheric nitrogen; while others cause plant and animal diseases, etc. Most bacteria are colorless, and none possess chlorophyll. The individual organism consists of a single cell, though a number of bacteria may be united into a thread or an irregular mass. Some bacteria are nonmotile, while others move by means of whiplike organs called *flagella* or *cilia.* Reproduction of bacteria takes place by fission and by asexual resting spores.

Bacteria are usually classified into the following four families:

1. Coccaceae, which are single spherical cells.
2. Bacteriaceae, which are cylindrical and straight.
3. Spirillaceae, which are spiral or bent.
4. Chlamydobacteriaceae (Phycobacteriaceae), which are cylindrical cells united into threads and surrounded by a sheath.

In the family Bacteriaceae the non-motile forms belong to the genus Bacterium;[1] the motile forms having the flagella distributed over the whole surface of the cells belong to the genus *Bacillus;* while the motile forms having the flagella confined to the ends belong to the genus *Pseudomonas.*

Nitrogen Bacteria, Bacillus Radicicola

Crush in water a tubercle from the root of a legume and examine the material under the high power of the microscope. Note the minute, colorless bacterial organisms. The tubercles are caused by these organisms which live in *symbiosis* with the leguminous plant. They receive organic food from the host plant, but in return they convert nitrogen from the air into a form which serves as a nutrient for the legume. Nitrogen compounds are added to the soil when the legume dies and its roots decay. The soil conditions which are favorable to the growth of these organisms are proper aeration, medium water-content, the presence of some organic material, and the absence of soil acidity. Draw several bacteria. Do you find the swollen, irregular forms called *bacteroides?*

Decay Bacteria

Many kinds of bacteria cause the decay of organic materials. They break down the dead bodies and excretions of plants and animals, so that these materials become a part of the soil. Most decay of this kind is useful to man; but some is harmful, because

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[1] There is some ambiguity in the use of the word **bacterium** (plural **bacteria**). The plural form, **bacteria**, is a general term used in referring to organisms belonging to the four families here distinguished; while the word **Bacterium** is the name of a single genus.

food is destroyed in this way. What are the principal ways of preserving food, and how does each of these aim to control bacterial activity? Examine a portion of a decayed fruit for bacteria. Draw several bacteria. Make an outline of the relation of bacteria to man, giving (1) the ways in which they are beneficial and (2) the ways in which they are harmful.

2. *Cyanophyceae: Blue-green Algae*

The *Cyanophyceae* are one-celled or filamentous Schizophytes, which are bluish green in color because they contain a blue pigment called phycocyan in addition to chlorophyll. Frequently, they are united into colonies by swollen gelatinous cell walls. They are usually much larger than bacteria. They often live in water or form blue-green masses on damp soil, rocks, and similar places. *Reproduction* of these organisms usually takes place by cell division. Also, in some kinds, another method of reproduction is found; a group of a few cells separates from the filament, and, after moving about for a time, this group comes to rest and develops into a new filament. They may also form large, thick-walled, resting spores. Some forms produce occasional larger cells in the filament, which are called *heterocysts.* These provide breaking places for the filaments. The most important families of the filamentous forms are the *Oscillariaceae* and the *Nostocaceae.*

Oscillaria

Oscillaria occurs in filaments composed of very short cylindric cells, placed end to end and surrounded by a gelatinous sheath. Reproduction takes place by cell division in all parts of the filament, and by the breaking apart of the filament at various points. The cell walls are rounded at the ends of the filaments, because there is nothing to counteract the pressure within the cell. Find a place where the filament is about to divide. The name *Oscillaria* is given to this organism because the ends of the filaments swing backward and forward. Make a drawing (4 cms. wide) of a filament as seen under the high power of the microscope.

Nostoc

Dark green gelatinous masses of these organisms may be found on moist soil or in water. Examine some of this material under the microscope. Note the filaments of small elliptical cells, placed end to end like a string of the beads. Find the larger, colorless cells in the filaments. These are the *heterocysts,* which serve as places where the filaments divide. Do you find a gelatinous sheath surrounding a group of filaments? Make a drawing (4 cms. wide) of a single filament, including a heterocyst.

Gleocapsa

Collect specimens of *Gleocapsa* which may be found forming dark green masses on moist soil, rocks, tree trunks, walls, etc.

Examine some of the material under the microscope. Spherical *Gleocapsa* cells may be seen clinging together in groups enclosed by soft gelatinous walls that surround several of the unicellular organisms. When a cell divides the daughter cells remain within the gelatinous sheath that enclosed the original mother cell. Make a drawing (4 cms. wide) of a group of these organisms.

B. FLAGELLATA: FLAGELLATES

Examine with a microscope some specimens of *Euglena.* Where were these obtained? Are the organisms green or are they colorless? Do they manufacture their own food? Is the organism composed of a single cell or of several cells? Can you discover a nucleus? Whip-like organs which are used by this organism for locomotion are called *flagella.* Which end is forward as the organism moves through the water, the end bearing the flagellum or the opposite end? The flagellates that are living at the present time are primitive aquatic organisms which are supposed to be similar to the ancestors of unicellular animals as well as of unicellular plants. They commonly reproduce by longitudinal division. In addition, some forms produce thick-walled *resting spores.* But sexual reproduction is absent. Make a drawing (10 cms. long) of a specimen of *Euglena.*

C. MYXOMYCETES: SLIME MOLDS

Examine specimens of *Trichia sp.* and of *Stemonitis sp.* Note the slimy mass of naked protoplasm, called the *plasmodium.* The plasmodium is found in damp, shaded places, where it spreads slowly over decaying wood, banana stumps, etc. The plasmodium consists of a mass of protoplasm containing many small nuclei. Do the organisms contain chlorophyll? Do they manufacture their own food? How do they obtain their food? Just before spore formation, the plasmodium moves toward the light, and becomes converted into spore-cases or *sporangia,* containing asexual spores. Examine sporangia with a hand lens. Note the stalk, the wall, and the internal structure called the *capillitium,* which surrounds the spores. The spores grow into *motile zoospores,* which divide a number of times and finally unite to form a new plasmodium. Draw, with the aid of the hand lens, the plasmodia and sporangia of *Stemonitis sp.* and *Trichia sp.*

D. DIATOMEAE: DIATOMS

Examine under the high power of the microscope some water from a rice field. Find small cylindrical, wedge-shaped, or rhomboidal cells, having minute markings on their walls. Note that the walls consist of two halves, called *valves,* one of which fits over the other. The walls contain a glass-like substance called *silica.* Look for a central nucleus and a brownish-yellow chloroplast. Reproduction is accomplished by longitudinal cell division, and also at intervals by the formation of a kind of spore. Dia-

toms are abundant in both fresh and salt water, and form the food of small animals, and thus indirectly of fish. The deposits of the siliceous valves of diatoms are used as a powder for polishing metals and as a constituent of dynamite. Make drawings of five different forms, showing clearly the markings on the walls.

II. PLANTS

A. ALGAE

Algae are very primitive plants which contain chlorophyll and which, therefore, manufacture their own food by the process of photosynthesis. The algal plant body is of a simple kind called a *thallus,* which is not differentiated into well-developed root, stem, and leaf, and true tissues, as are the bodies of higher plants. In the vegetative stage most algae are without the power of locomotion. An algal cell contains one or more chloroplasts and usually contains a single nucleus, though a single cell may contain several nuclei,—a cell containing several nuclei is called a *coenocyte.* Algae as here defined may be divided into two groups, which are usually distinguished most easily by their color: (1) *Chlorophyceae,* the green algae, most of which live in fresh water, and (2) *Rhodophyceae,* the red algae, which contain a red pigment in addition to chlorophyll, and which inhabit salt water almost exclusively.

1. Chlorophyceae: Green Algae

The *Chlorophyceae* or *green algae* are small plants having a bright chlorophyll-green color. Most of the green algae live in fresh water, though a few live in moist shaded places on land and some live in salt water. Some are visible only with a microscope; others form threads that are visible to the naked eye; while still others are quite large. More than 9000 species of Chlorophyceae are known; these species differ greatly in size, form, and habit. None of the *Chlorophyceae* are of economic importance. Nevertheless, many are of great scientific importance, because they illustrate important features of the *evolution of sex* in plants. In some cases the plant body is composed of single cells, in others of simple or branched filaments, and in others of plates or colonies of cells. Each cell contains a nucleus and one or more chloroplasts. The chloroplasts manufacture carbohydrate food. In one group the thallus is composed of multi-nucleate cells.

The *Chlorophyceae* differ greatly in their reproductive methods. Most of them develop *free-swimming asexual swarmspores or zoospores,* which move by means of *cilia* (small hairlike outgrowths capable of vibratory movement), and are able to reproduce the plant directly. In addition, many of them possess sexual methods of reproduction, by means of sexual cells called *gametes.* In the more primitive forms the *gametes* are alike (*isogametes*), and resemble the zoospores. By union (*conjugation*) of two similar gametes, a *zygospore* is produced; the zygospore may develop into zoospores or may give rise directly to new invividuals.

In the higher forms the gametes are not alike (*heterogametes*); these gametes are of two kinds; (1) small male gametes or *sperms* and (2) large female gametes or *eggs*. Sperms are formed in structures called *antheridia* and eggs in structures called *oogonia*. By the union of a sperm with an egg (*fertilization*) an oospore is produced; this may develop directly into a new individual or it may form motile zoospores.

a. *Pleurococcus*

Pleurococcus may be found as a bright green growth on the trunk of bamboo and in similar locations. Place some of this material in a drop of water on a slide; put on a cover glass and examine with the low and high powers of the microscope. The individual organism is composed of a spherical cell which has a transparent cellulose wall, a single nucleus, and several large chloroplasts. These cells reproduce by cell division, and they may be seen clinging together in irregular groups. No other method of reproduction of this alga is known; its life history is very simple. All other plants are supposed to have originated by a process of gradual evolution from a primitive type of plant resembling *Pleurococcus*. Draw several groups of these algae, make your drawing sufficiently large to show all the details of structure which you are able to see.

b. *Oedogonium*

This green alga is often found in ponds and streams. Mount some of the material in water on a slide, and examine with the microscope. The plant body consists of a chain of cells which form an unbranched filament, attached at the lower end by a special cell called a *hold-fast*. The filament is composed chiefly of bright green cylindrical vegetative cells, but may contain in addition reproductive cells of one or more types. Each vegetative cell in the filament contains one nucleus and a chloroplast which lines the cell wall. *Asexual reproduction* takes place by means of large motile *zoospores*, each of which is formed from the entire contents of a single cell. The zoospores escape by the rupture of the cell walls. At one end of a zoospore is a ring of *cilia*, by means of which it moves. A zoospore develops directly into a new filament. Sexual reproduction takes place by the *union of unlike gametes*. A cell of the filament may swell and its entire contents may become a female gamete or *egg*. A cell that contains an egg is an *oogonium;* this develops a small opening at one end, through which the male gametes or *sperms* may enter. The sperms are produced in small, shortened cells, called *antheridia*. Each sperm is small and moves about by means of a ring of cilia at one end. *Fertilization* takes place when a sperm, which has entered the oogonium through the special opening, unites with the egg. As a result of fertilization a thick-walled *oospore* is formed. From the oospore four zoospores are developed, each

of which may germinate into a new filament. Make a drawing (4 cms. wide) of small portions of filaments showing an oogonium, antheridia, and vegetative cells.

c. Spirogyra

Spirogyra is a filamentous green alga which forms a green scum near the surface of the water in ponds, rice fields, and slowly flowing streams. The masses feel slippery to the touch. The individual filaments of which the scum is composed are barely visible to the naked eye.

Examine a few filaments of *spirogyra* under the microscope. It will be seen that each filament is composed of a row of similar cylindrical cells placed end to end. The filament is unbranched. The cell walls are smooth and are composed of cellulose. The most conspicuous parts of the cell contents are the chloroplasts. These are ribbon-like green bands that are wound spirally just within th cell wall. How many of these chloroplasts do you find in each cell? Note the roundish bodies, called *pyrenoids,* which are embedded in the chloroplasts. The pyrenoids serve as places for accumulation of starch. The nucleus may be distinguished as a dense grayish mass, lying within the nearly transparent cytoplasm. Note the large central vacuole filled with cell sap.

Reproduction may take place by an asexual process. Each cell of the filament is capable of division into two cells; the filaments increase in length by such cell division; breaking of the filament may form new filaments.

Sexual reproduction takes place by the simple process called *conjugation.* Cells of two filaments lying side by side send out protuberances which meet. The walls of the protuberances become dissolved at the point of contact, so that the cells of one filament are connected by short tubes with the cells of the other filament. The contents of the cells of one filament then pass over into the cells of the other filament and unite with the contents of these. This primitive sort of sexual reproduction, in which two similar gametes fuse, is called *conjugation.* The result of this conjugation is a *zygospore,* which is a thick-walled resting spore. The zygospore germinates and forms a new filament.

Make a drawing (4 cms. wide) of a portion of a filament. Label all parts. Make drawings to show stages in the process of conjugation.

B. FUNGI

Fungi are simple plants which are destitute of chlorophyll and reproduce mainly by means of spores. The vegetative body of a fungus is a simple thallus built up of essentially independent threads. These vegetative threads are called *hyphae* (singular *hypha*[1]) and the mass of hyphae is called the *mycelium.*[2] Since

[1] Hypha; from Gr. **hyphe**, a web.
[2] Mycelium; from Gr. **mykes**, a fungus.

fungi have no chlorophyll, they are without the power of manufacturing carbohydrate food. Fungi must therefore depend upon other plants or animals for their food. A fungus which obtains its food from some living organism (called its *host*) is a *parasite;* while a fungus which derives its food from dead or decaying organic matter is a *saprophyte,* and the organic substance upon which it lives is called the *substratum.* Parasitic fungi frequently send special food-absorbing outgrowths, called *haustoria,* into the tissues of the host.

Fungi are classified into three great groups, as follows:

Class I.	Phycomycetes	Algal Fungi.
Class II.	Ascomycetes	Sac Fungi.
Class III.	Basidiomycetes	Basidia Fungi.

A fourth group of fungi, called *Fungi Imperfecti,* is made to include those fungi which cannot be assigned to any of these three groups.

I. Class I. Phycomycetes: Algal Fungi

These fungi are characterized by the absence of cross-walls (*septa*) in the hyphae. Cross-walls occur only in spore-bearing branches and rarely in old hyphae. The hyphae contain many small nuclei. Reproduction takes place by asexual spores, and also by spores produced sexually. Many Phycomycetes are parasitic on land plants; others live in water, some as parasites and others as saprophytes.

1.

Class: Phycomycetes: Algal Fungi
Sub-class: Zygomycetes
Order: Mucorales
Family: Mucoraceae
Genus: *Rhizopus.*
Black Mold or Bread Mold.

Place a small piece of moist bread in a tumbler and cover to keep moist. In two or three days the material will be ready for study. Note that the bread has become covered with a fine white growth, bearing erect threads. Examine the moldy bread with a hand lens. The white mold covering the bread is the *mycelium,* composed of a mass of interwoven fungus threads called *hyphae.* Note that the erect hyphae bear spherical structures at their tips. These are spore cases, or *sporangia,* each of which contains many black asexual *spores.* These spores are carried by the wind and are capable of germinating to form a new mycelium.

The erect hyphae bearing sporangia are called *sporangiophores.* Note that the sporangiophores, bearing sporangia, occur in groups. How many sporangiophores occur in each group?

How is one group connected with the next group? Do you find any special hyphae that attach each group to the bread? Make a drawing (5 cms. long) showing two groups of sporangia.

With the point of a knife remove a small portion of the fungus bearing white (young) sporangia. Remove another portion bearing black (old) sporangia. Mount each portion in alcohol, followed by a drop of water.(a) Examine these under the low power and then under the high power of the microscope. Note that the vegetative hyphae have no cross-walls. This usual absence of *septa* in the mycelium is a characteristic of all *Phycomycetes.* Describe the contents of a hypha. Can you distinguish the nuclei?

Now examine carefully the young and old sporangia. What is the color and appearance of the asexual spores within the sporangia? Compare a young, unopened, sporangium with one in which the outer membrane has broken. What portion of the whole sporangium structure is filled with spores? Observe that the spores fill the space between two membranes: an outer membrane, and an inner one that is a part of the central axis, called the *columella.*

Draw under the high power of the microscope a small portion of a hypha. Make a drawing showing a young sporangium in which the external membrane has not broken. Make another drawing showing an old sporangium in which the outer membrane has broken and showing the spores clinging to the columella. Draw three spores under the high power of the microscope.

2.

Class: Phycomycetes
    Subclass: Oomycetes
        Order: Peronosporales
            Family: Peronosporaceae
                Genus and species: *Sclerospora maydis*
                    Host: *Zea mays*
                        Downy Mildew of Corn.

Early in the morning examine a corn plant infected with this parasite. What symptoms do you observe? The diseased portions of the leaf are yellowish in color; such loss of green color is called *chlorosis.* Through interference with what process of the leaf does injury probably result? What finally happens to the diseased portion of the leaf or to the whole leaf? Can you distinguish diseased from healthy plants in the field? At what age do plants first show symptoms of disease?

Examine with the hand lens the short white threads that grow out from the diseased portion of the leaf and bear oblong spores. Do you find these threads on both surfaces of the leaf? These threads are stalks bearing asexual *conidiospores or conidia.* Conidia are asexual spores which become separated from the tips of special hyphal branches. Conidia are not enclosed in sporangia. Are the

spores produced at night or during the day? Draw a diseased leaf showing diseased and healthy portions.

Remove some of the conidia-bearing hyphae (*conidiophores*) and examine them under the low power and high power of the microscope. Strip some of the epidermis from the diseased portion of the corn leaf; examine this under the microscope and determine whether or not each conidiophore comes out of the leaf through a stoma. Examine carefully the conidia at the ends of the branches of the conidiophores. Describe the color and shape of the conidia. Where is the vegetative mycelium of the fungus? What is the advantage to the fungus of having the conidia borne on stalks in the air? How might the fungus be transferred from one plant to another? Is the mycelium septate? Make a drawing (5 cms. long) of a single conidiophore, bearing conidia.

Discuss the extent of the damage done by this disease and means of control.

3.

Additional Fungi Belonging to the Group Phycomycetes

Study one of the following fungi:

Phytophthora faberi .... on Cacao
Peronospora sp. .... on Soy Bean
Phytophthora colocasiae .... on Gabi

4.

Methods of Controlling Plant Diseases

(1) *Destruction of diseased parts.* The diseased part should be removed and burned, to destroy any spores that it may contain or which might mature later. General methods of *sanitation* should be employed.

(2) *Preventing infection.* Spores may be destroyed by the use of chemicals (fungicides) or by heat.

Soil sterilization is necessary in the case of many organisms which live in the soil and attack the plant as it germinates. A chemical, such as formaldehyde, may be used, but in general heat is the best agent.

Seed sterilization, with chemicals or hot water, may be used to kill spores that are attached to the seed. Particular care should be observed with seeds and plants brought in from other regions; such seeds and plants should be carefully inspected for spores or disease. The seeds should be sterilized, and plants showing symptoms of disease should be isolated, or placed under *quarantine.*

Spraying the aerial parts of the growing crop with a fungicide, such as Bordeaux mixture, is used for checking many diseases. When spores fall on the sprayed parts, the spores or the mycelium produced by the spores may be destroyed.

Seed selection may be used to prevent disease. Plant only seeds which are free from spores and mycelium.

Destroy weeds, volunteer grains, secondary hosts, and other plants that may harbor the disease and thus infect the crop.

Crop rotation is advantageous in checking many diseases which are carried by means of spores or mycelium living in the soil.

Plant selection and breeding may be employed in order to obtain varieties which are resistant to plant diseases.

(3). *Composition of fungicides.* Fungicides are preparations that are applied to living plants for the prevention of disease caused by parasitic fungi. To be of practical value a fungicide should destroy the parasite without doing serious harm to the host. Furthermore, it should be easy to prepare and apply, and should be cheap. Most fungicides contain some form of copper or sulphur. Two of the best fungicides are the following:

(a.) *Bordeaux mixture.* This is probably the most valuable fungicide known. It is made of copper sulphate, *unslaked* lime, and water. A common formula is the "2.27-2.27-189", that is, 2.27 kilograms of copper sulphate, 2.27 kilograms of *unslaked* lime and 189 liters of water. Other formulae, such as "2.72-1.81-189", "1.81-1.81-189", and "1.36-1.36-189" are also used. This mixture is applied as a spray, by means of a spray pump provided with a nozzle that will produce a fine spray. For spraying during the rainy season it is best to add to the Bordeaux mixture, a so-called *sticker,* which will cause the film of Bordeaux mixture to adhere better to the plant surface. A satisfactory sticker is composed of 1 kilogram of *resin,* 0.5 kilograms of sodium carbonate, and 3.8 kilograms of water.[3]

(b.) *Lime-sulphur.* This is employed extensively as an insecticide and also as a fungicide. It is prepared by boiling in water proper quantities of unslaked lime and flowers of sulphur. This mixture is applied as a spray.

2. *Class II. Ascomycetes: Sac Fungi*

The name Sac Fungi or Ascomycetes (from *ascus,* sac, and *mycetes,* fungi) is given to this group because the spores are borne in sacs or *asci.* The asci may be cylindrical, club-shaped, or oval. Each ascus commonly contains 8 *asco-spores.* The sacs are usually present in large numbers and are generally grouped into fructifications called *ascocarps.* The layer of asci in the ascocarp is called the *hymenium.* Classification is chiefly based upon the forms of ascocarps. An open cup or saucer-shaped asocarp is called an *apothecium,* while a closed ascocarp is called a *perithecium.* Ascomycetes may also reproduce by *conidia* or by thick-walled spores called *chlamydospores.*

[3] For preparing Bordeaux mixture it is absolutely essential to use a good grade of unslaked lime and to carefully follow directions. See Reinking, O. A., Philippine economic-plant diseases. Philippine Journal of Science, Section A, 13: 165-274. 1918.

1.

Class: Ascomycetes
Subclass: Euascomycetes
Order: Pezizales
Family: Pezizaceae
Genus: *Peziza*

Is this fungus parasitic or saprophytic? Upon what *substratum* does this species of Peziza grow? What is the general shape of the fruiting body? Is the surface smooth?

Make a drawing (5 cms. long of the fruiting body and its substratum.

Cut your specimen through the center, from the top to the base of the cup. Study with a hand lens the cut surfaces. Then mount in dilute glycerin thin sections which have been cut through the fruiting body. Examine one of these sections under the microscope. Find elongated sacs containing spores. How many spores do you find in each sac? How are these sacs placed with respect to the fruiting body? This layer of spore-bearing sacs is called the *hymenium*. Each sac is called an *ascus*. The spores contained in an ascus are *ascospores*. A fruiting body such as this, bearing asci, is called an *ascocarp*. An ascocarp that is open and saucer-shaped, it is called an *apothecium*. Examine your specimen for sterile hyphal threads called *paraphyses* (singular *paraphysis*) which occur between the asci. Make a diagram (10 cms. long) showing a vertical section of the apothecium. Show the hymenium and draw some of the asci in position. Make a drawing (15 cms. long) of a single ascus containing ascospores. Make a similar drawing of a paraphysis.

Examine under the microscope a small portion of the substratum near the place where the apothecium was attached. Find the hyphae which form the vegetative mycelium. Does the mycelium have cross walls or septa? How does it differ from the mycelium of the Phycomycetes which you have studied? Draw a small portion of the mycelium.

2.

Class: Ascomycetes
Subclass: Euascomycetes
Order: Dothidiales
Family: Dothidiaceae
Genus and species: *Phyllachora sorghi*
Host Plant: *Andropogon sorghum*

Examine a leaf infected with *Phyllachora sorghi*. Note the black masses sunken in the leaf. These are the *stromata* (singular *stroma*). *Stromata* are firm masses of mycelium which bear asci on their surfaces, or which enclose asci. Is the leaf dying or dead around each stroma? Describe the appearance of the diseased leaf. Make a drawing of a portion of the leaf, showing stromata.

Examine a cross section of the leaf, showing the stromata in cross section. Note that the black stroma is united with the parenchyma and epidermis of the leaf. Inside the stroma find a cavity which contains cylindrical *asci.* Does each ascus contain eight ascospores? This cavity and the surrounding stroma is the ascocarp. Such a spherical or flask-shaped ascocarp is called a *perithecium.* In this fungus the perithecium is sunken in the stroma. Note that each perithecium possesses a small opening (*ostiole*) by means of which *asci* or *ascospores* may escape. Look for sterile filaments that lie between the asci and do not contain spores. These are the *paraphyses.* Make a diagrammatic drawing (10 cms. long) of a portion of the leaf, showing *stromata, perithecia, asci, ascospores* and *paraphyses.*

Examine several asci under high power. Do these asci always contain eight spores? What is the color of the spores? What is their shape? Make a drawing (8 cms. long) of a single ascus, containing ascospores. Is each spore one or two-celled?

With what processes of the leaf do you suppose the fungus interferes the most? Estimate the extent of damage done by this disease. What methods of control would you advise?

3.

Class: Ascomycetes
Subclass: Protoascomycetes
Order: Saccharomycetales
Family: Saccharomycetaceae
Genus: *Saccharomyces*
Yeast.

Study material that has been growing in a dilute solution of sugar or in bouillon (meat extract). Mount some of the fungi in water and study under the high power of the microscope. Are the yeast plants uniform in size? Is their shape spherical, ellipsoid, ovoid, or pyriform? Make a drawing (6 cms. long) of a single yeast plant.

Note that new individuals, or *buds,* grow out from the bodies of the parent plants. Make outline drawings to show three stages in the budding process. Do the cells cling together into colonies after the formation of daughter cells?

Study a thick-walled cell in which four spores have been produced. Such a cell is considered an *ascus.* The four spores are therefore ascospores. Make a drawing to show these.

In its growth yeast converts sugar into alcohol and carbon dioxide gas (as well as several minor products). This property of producing the fermentation of sugar gives yeast great economic importance. Alcohol is produced by the action of yeast upon the sugary saps of the nipa palm, buri palm, sugar palm, coconut, etc. Yeast is also used in making bread. In this case the carbon

dioxide gas is the important product. This gas raises the bread and produces the holes in the bread when it is baked. Of course alcohol is also produced, but most of this evaporates while bread is baking.

4.

Additional Fungi Belonging to the Group of Ascomycetes

Study one of the following fungi:

Phyllachora sp. .... on Wild Sugar Cane.
Micropeltis mucosa .... on Coffee.
Trichonectria bambusicola ...... on Bamboo.

3. Class III. Basidiomycetes: Basidia Fungi

The Basidiomycetes are the highest of the fungi. They include the edible saprophytic mushrooms, and also some very destructive crop parasites, the rusts and smuts. The Basidiomycetes comprise more than 18,000 species. They have probably evolved from the Ascomycetes. The Basidiomycetes take their name from a type of reproductive structure called a *basidium* which they possess. The typical basidium is a swollen terminal cell of hypha, from which are developed a group of four spores, called *basidiospores,* on delicate stalks called *sterigmata.* The basidium is a structure characteristic of the higher forms of Basidiomycetes. However, in certain lower types of Basidiomycetes, such as the smuts and the rusts, the basidium, or promycelium, bears little resemblance to the typical basidium. The mycelium of the Basidiomycetes differs from that of the Phycomycetes in being septate. The Basidiomycetes are distinguished from the Ascomycetes by bearing their spores on basidia, while Ascomycetes bear their spores in asci.

1.

Class: Basidiomycetes
Subclass: Eubasidii
Order: Agaricales
Family: Agaricaceae
Genus: *Agaricus*
Mushroom.

Study the fruiting body of *Agaricus.* Make a drawing (8 cms. long) to show: (1) the stalk or *stipe;* (2) the cap or *pileus;* and (3) the gills or *lamellae,* which are thin projections from the lower surface of the pileus. Do you find a cup-like structure, called a *volva* at the base of the stipe? Is there a ring (*annulus*) around the stipe?

Cut vertically through the center of the pileus so as to split the stalk where it is attached to the pileus. Make a drawing (6 cms. long) of the section of the pileus and upper end of the stipe. Do all of the gills run from the margin of the pileus to the stipe? Are the gills free, or are they united with the stipe? Make a

diagram of a portion of the pileus as seen from below, to show the arrangement of the gills.

Mount a single gill in dilute glycerine on a slide and examine the edge of the gill under the microscope. If the gill is very thick, use a section of the gill. Look for *basidia,* which may be recognized as swollen hyphal tips, on which are borne basidiospores on fine stalks called *sterigmata.* How many spores are borne on each basidium? Make a drawing (6 cms. long) of a basidium with spores. Make a diagram of the cross section of a gill showing where the spores are borne. Label the layer in which the basidiospores are found the *hymenium.*

Carefully tear apart small pieces of the stipe and of the pileus. Are the stipe and pileus composed of thread-like hyphae? Are the hyphae septate? Are they branched?

Obtain a spore print by cutting off the stipe and placing the cap (gills down) on a sheet of white paper under a bell jar. After 24 hours, examine the print. Are the spores black, brown, rusty, pink, or white in color?

2.

Class: Basidiomycetes
Subclass: Eubasidii
Order: Agaricales
Family: Polyporaceae
Genus: *Polyporus*

Polyporus commonly grows on tree trunks. The spores are borne in bracket or shelf-like sporophores growing out from the tree. Examine the lower surface with a hand lens. Note the small pores. The vegetative mycelium grows through the wood of the tree and absorbs food from it. Make a drawing of the sporophore. Study a section which has been cut across the pores. Make a diagram of ten pores, showing the position of the hymenium. Find and draw a basidium which bears four basidio-spores on *sterigmata.* How are these fungi of economic importance?

Hemibasidii and Protobasidii

The typical Basidiomycetes, such as *Agaricus* and *Polyporus,* bear their spores directly from the mycelium at the tip of the club-shaped structures called basidia. The spores (usually four in number) are borne on the ends of the short stalks called *sterigmata.* But in the more primitive *Hemibasidii* (the Smuts) the basidia are not typical. In the Hemibasidii spores are borne free, that is, not on stalks. The spore germinates, producing a tube called the *promycelium.* This promycelium corresponds to the basidium, and bears basidiospores (like conidia) which may be more than four in number and may be produced at the sides as well as at the tips of the promycelium. In the slightly higher

group of *Protobasidii* the spores are borne on stalks. The basidia are septate and arise from a resting spore or are borne directly on a hymenium. In the group Uredinales (or rusts, belonging in the subclass *Protobasidii*) the basidia are septate with cross walls; they arise from resting spores. The rusts are all parasitic, and usually have a *polymorphic* life history; that is, they usually have two different kinds of host plants and have a distinct form on each.

Copy from a textbook (e. g., Ganong, W. F., *A textbook of botany for colleges.* New York, 1917) drawings to show the complete life history of wheat rust, *Puccinia graminis.* Be sure to indicate the source of your drawings.

3.

Class: Basidiomycetes
Subclass: Protobasidii
Order: Uredinales: Rusts
Family: Pucciniaceae
Genus and species: *Hemileia vastatrix*
Coffee rust.

Collect and study coffee leaves which are infected with this parasite. What is the color of the spots? Are the spots found on both surfaces of the coffee leaf? Are they regular in shape? How are they distributed on the leaves? Draw a diseased leaf.

Scrape spores from the surface and mount these in dilute glycerine on a slide. Study with the microscope. Do you find uredospores? These are pale yellow, one-celled, spores, that are slightly obovate, flattened and smooth on one side and rough and rounded on the other. Do you find *teleutospores?* These are one-celled spores which are similar to the uredospores, but differ in being lighter in color and in being smooth on both sides and in bearing a small beak at the extremity. Draw (4 cms. long) two uredospores under the high power. Show accurately the shape and the contents of the spores, and the appearance of the walls.

Obtain a thin cross section of the leaf through a spot. Mount this in dilute glycerin and examine under low and high power of the microscope. Make a diagrammatic drawing of the spot and a portion of the surrounding leaf tissues, showing the way in which the spores are borne.

Scrape spores from the surface of the leaf and put these in a drop of pure water on a slide. Do not put on a cover glass. Place the slides on a wet cloth in a dish and cover with a bell jar. On the next day put on a cover glass and examine the slide under high power. Have the spores germinated? Make a drawing (4 cms. long) of a germinating spore.

In the typical Uredinales the teleutopores produce in germination a basidium-like filament (*promycelium*) which is generally

divided into four cells, from each of which arises on a slender filament (*sterigma*) a small, thin-walled basidiospore.

What measures are advised in controlling this disease? What success can be obtained with these control measures? Explain why the price at which coffee is sold would determine the practicability of spraying with a fungicide. Discuss sanitation and plant breeding as means of control. Discuss the relation of altitude to the production of coffee.

4.

Class: Basidiomycetes
  Subclass: Protobasidii
    Order: Uredinales: Rusts
      Family: Pucciniaceae
        Genus and species: *Puccinia purpurea*
          Rust of sorghum.

Examine leaves of Sorghum which are infected with this disease. From its appearance, how would you distinguish the rust from the disease caused by *Phyllachora sorghi?* How are the rust *pustules* distributed? What is the color of the pustules? On which surface of the leaf are they most numerous? Were they formed outside the epidermis or under it? State evidence for your answer. Draw a portion of the leaf to show rust pustules.

Examine under the microscope a thin section of the leaf through a pustule. How are the pustules formed? Do you find more than one kind of spore? *Uredospores* of this fungus are *one-celled,* ovoid, smooth, and are brown in color. The *teleutospores* are *two-celled,* elongate, ovoid, and are darker brown in color. What is the most easily observed difference between the teleutospores of *Hemileia* and of *Puccinia.* Make a diagrammatic drawing of a pustule, showing the fungus and a portion of the host. Show the mycelium and the way the spores are borne. Draw (4 cms. in diameter) two spores of each kind, showing accurately the character of the walls and of the spore contents.

Germinate spores by the method used with coffee rust. Draw a germinating spore.

Discuss the methods of controlling this disease. Even though it prevented the growth of the fungus, do you think that spraying would pay? What measures of sanitation would you advise?

Make a list of five other species of rusts and their hosts.

5.

Additional Fungi Belonging to the Group of Basidiomycetes

Study one of the following fungi:

Ustilago sacchari .... on Sugar Cane
Puccinia kuehnii .... on Sugar Cane
Aecidium blumeae .... on Blumea balsamifera
Aecidium sp. .... on Alchornea rugosa.

4. Fungi Imperfecti: Imperfect Fungi

These are fungi having a septate mycelium which cannot be classified in any of the three main groups—Phycomycetes, Ascomycetes, or Basidiomycetes. The imperfect fungi include fungi for which ascospores, basidiospores, or sexual spores have not been discovered. They commonly reproduce by asexual conidia. Spores may be unknown. The genera are made on an artificial basis and are called *form-genera.* There are about 17,000 imperfect fungi. Many of these may be assigned to the Ascomycetes or Basidiomycetes more is known of their life history.

There are three principal ways in which spores are borne: (1) in *pycnidia,* (2) in *acervuli,* and (3) on *freely exposed conidiophores.*

(1) *Pycnidia* are more or less spherical hollow receptacles on the inside of which spores are borne on stalks. (2) *Acervuli* are essentially pycnidia without walls. An acervulus consists of a close layer of sporophores bearing spores. (3) The third kind of fructification has conidiophores which grow free for some distance, so that the terminal parts of the conidiophores stand as separate threads.

The imperfect fungi are very destructive, since they often occur as parasites on leaves, stems, fruits, wood, bark, etc. On leaves they are particularly common, causing diseased areas known as *leaf spots.*

1.

Class: Fungi Imperfecti
Order: Melanconiales
Family: Melanconiaceae-Hyalophragmiae
Genus and species: *Septogloeum arachidis.*

Collect diseased leaves of *Arachis hypogaea,* peanut. The *leaf-spots* are circular, dark-brown or black spots, surrounded by yellow rings. In advanced stages, the leaves become yellow and drop from the plant.

1. Examine the spots for powdery cushions of spores. On which surface of the leaf do you find the powdery masses of spores? Are all of the spots circular in shape? Are the powdery spots raised or sunken? Do you find any spots on the petioles or stems of the plant, or only on the leaves? Make a drawing (xl) of an infected leaf, showing the position and shape of the spots.

2. Examine under the microscope sections cut through a spot. Do you find dark colored cushions of hyphae running between the leaf cells and sending haustoria (sucking organs) into the leaf cells? Is the mycelium septate? How is the fruiting body formed? Is it formed under the epidermis and does it later break through? Do you find the conidia borne on tubular conidiophores? Are the spores borne (1) on the exposed conidiophores, (2) on

short sporophores arising from a stroma produced beneath the epidermis, or (3) on short sporophores in flask-shaped cavities? Are the conidiophores septate or not? Are the conidia one or several celled? Compare conidia and conidiophores as to length, septations, markings, and color.

Make a diagrammatic drawing showing the position of the fruiting body with respect to the host tissues, and also the positions of conidiophores and of conidia. Make a drawing (10 cms. long) of the three conidiophores bearing conidia. Also, draw four conidia that have broken away from the conidiophores.

3. Suggest methods of controlling this disease. Do you think it would be possible to introduce the disease by bringing in seed carrying spores? If so, what kind of seed treatment might be used? Explain why the density of the peanut foliage would appear to make spraying unsatisfactory. What sanitary measures should be used? Would crop rotation be effective? Should resistant varieties be tested?

2.

Class: Fungi Imperfecti
Order: Melanconiales
Family: Melanconiaceae-Phaeosporae
Genus and species: *Melanconium sacchari*
Rind disease of Sugar Cane.

Collect diseased sugar cane stems and examine them for small black pustules or openings. Diseased canes which have stood in the laboratory for several weeks will show curled, hair-like black threads coming out from the minute pores in the stem. Each thread consists of a mass of spores distributed through a gelatinous substance. Do you find discolored and shrunken areas on the stem? Are the pustules most abundant on the nodes or on the internodes? Draw a portion of the stem to show the symptoms of the disease.

With a knife cut into the diseased cane. Has the fungus produced discolorations or any other abnormal appearances in the tissue of the cane? Does the cane become light in weight and shrunken in the diseased parts? Do you think that the cane is greatly injured by the disease?

Examine under the microscope a thin section cut through a diseased portion of the stem. What is the form of the pustule? Are the pustules closed and situated beneath the epidermis or are they open and without walls? Do you find a thread composed of a minute brown or black conidia? Examine the conidia. Observe that they are cylindrical and dark in color.

Make a drawing (10 cm. long) of a pustule, showing the way in which the conidia are produced. Also show the host tissues around the pustule. Draw a small portion of the gelatinous thread

containing spores. Draw the spores 2 cms. long. Discuss control measures.

3.
Additional Imperfect Fungi.

Study one of the following:

1. *Helminthosporium inconspicuum* .... on Corn.
2. *Cercospora lussoniensis* .... on *Phaseolus sp.*
3. *Phyllosticta sp.* ..... on fruit and leaf of Egg Plant.
4. *Pestalozzia palmarum* .... on Coconut leaf.
5. *Lasiodiplodia theobromae.*
   on Cacao pod, Sweet potato, etc.

4.
Economic Importance of Fungi

Make an outline showing the economic importance of fungi to man. In the outline show (1) the ways in which fungi are harmful, and (2) the ways in which fungi are beneficial. Illustrate each topic in your outline by at least one example of a fungus.

C. BRYOPHYTA: BRYOPHYTES: MOSS PLANTS

The *Bryophytes* are small plants which usually live in moist, shady places, where they form green cushions on moist soil, stones, or tree trunks, and rarely grow more than a few centimeters in height. The plant body may be a thallus or may be differentiated into simple structures resembling roots, stems, and leaves,—though it never contains a fibrovascular system. The Bryophytes have descended from green algae. They possess a female reproductive organ called an *archegonium.* The typical archegonium is a flask-shaped structure which encloses the *female gamete* or *egg.* The Bryophytes pass, in their life-history, through two *alternating generations.* These alternating generations are (1) the *gametophyte* (gamete plant) or sexual generation, which produces *gametes;* and (2) the *sporophyte* (spore plant) or asexual generation, which produces *spores.* The number of chromosomes in the nuclei of the sporophyte (2x) is twice as great as the number in the nuclei of the gametophyte (x). The life-history may be illustrated by the following diagram:

Male gamete

Spore—Gametophyte ⟨ ⟩ Zygote—Sporophyte
—Spore.

Female gamete

In the Bryophyta the gametophyte is the more highly developed generation, being the *plant,* as commonly recognized, while the sporophyte generation is comparatively undeveloped, never exhibiting organs resembling stems and leaves.

The Bryophytes are divided into two groups: (1) *Hepaticae* or Liverworts, and (2) *Musci,* or True Mosses. The differences between these will become evident after studying types in the laboratory.

1.

Bryophyta: The Moss Plants
Hepaticae: The Liverworts
Anthoceros sp.

a. *The Gametophyte.* Examine specimens of the plant. Note that the plant body is a thallus, which is irregular in outline. Find the rhizoids which grow from the lower surface. These absorb, from the soil, water and dissolved materials. Does the plant contain chlorophyll? How does the plant increase in area? The liverwort thallus is the gametophyte and produces *female gametes* (*eggs*) in archegonia and *male gametes* (*sperms*) in *antheridia.* Archegonia and antheridia develop from cells beneath the upper surface. The antheridia liberate motile *sperm cells* (*male gametes*). The female reproductive organs, or *archegonia,* are sunken in the thallus, the tip of the neck of the archegonium reaching the surface. Enclosed in each archegonium is a single *egg* (*female gamete*). Make a drawing of the gametophyte (x2). From prepared microscopic slides make drawings showing cross sections of antheridia and archegonia.

b. *The Sporophyte.* An egg cell, in an archegonium, is fertilized by a motile sperm cell from an antheridium. The fertilized egg (*zygote* or *oospore*) then gives rise by growth to the sporophyte. The lower part of the sporophyte becomes the *foot,* which remains sunken in the gametophyte. The *foot* supports the erect cylindrical portion of the sporophyte, which increases in length by growth at its base. Spores are formed from a cylinder of fertile tissue in the erect sporophyte. The cylinder of spore-producing tissue encloses an axis of sterile tissue and is surrounded on the outside by several layers of sterile cells. This sterile tissue which covers the spores contains chlorophll and is covered by an epidermis perforated by stomata. Draw (8 cms. long) the erect sporophyte. Draw (5 cms. long) a stoma as seen under the high power of the microscope.

c. *Spore mother-cells and spores.* Cut a portion of the sporophyte and draw a single spore mother-cell and several spores.

Questions: 1. Can the gametophyte of *Anthoceros* manufacture its own food? Why? 2. Is the sporophyte able to synthesize its own food? Why? 3. For what materials is the sporophyte dependent upon the gametophyte? 4. What organ does the sporophyte lack to make it a complete, independent plant? 5. Make a circular diagram to illustrate the complete life-history of *Anthoceros.*

2.

Bryophyta: The Moss Plants
Musci: The Mosses
Bryales: The True mosses
Moss.

a. *General habit.* Examine a plant with a hand lens. Make a drawing (10 cms. long) to show the general external appearance. The erect leafy portion is the *gametophyte* and the stalk portion bearing a cylindrical spore-case is the *sporophyte.*

b. *Gametophyte.* Study the erect stalks bearing leaves. How are the leaves arranged? Have the leaves petioles? Have they midribs? Describe the leaf margin and apex. Examine the base of the plant. Find the *rhizoids.* What are their functions? Find the prostrate, branched, filamentous growth, called the *protonema.* Study the protonema under the high power of the microscope. What is the color of the protonema? Describe the position of the cross-walls. Find a bud that will give rise to an erect leafy portion of the gametophyte.

Examine with a hand lens the tips of some of the leafy stalks which do not bear capsules. Careful search will show two kinds of structures (1) very small flask-shaped bodies, the *archegonia,* which contain *eggs,* and (2) club-shaped bodies, the *antheridia,* which contain *sperms.* Carefully remove the leaves at the tips of the stems, and draw (7 cms. long) under the low power of the microscope the *archegonia* and the *antheridia.*

In the antheridia are sperm cells which move in water by means of two cilia. The sperms swim to an archegonium, pass down the neck, and one sperm then fuses with the egg cell. The *fertilized egg,* or *oospore,* develops into the mature sporophyte composed of stalk and capsule. The oospore is the first stage of the sporophyte generation.

c. *Sporophyte.* The spore capsule (*sporangium*) and its stalk constitute the sporophyte. Remove the leaves at the base of the stalk. How is the sporophyte attached to the leafy gametophyte? Find a capsule that is capped by a loose conical cover, called the *calyptra.* The calyptra has developed from the upper part of an archegonium. Make a drawing (4 cms. long) showing the capsule covered by the calyptra.

Remove the calyptra. Examine with the lens the small cover, the *operculum,* at the top of the capsule. Make a drawing of the top of the capsule showing the *operculum,* as seen from the side. Remove the operculum and examine the exposed end of the capsule. Note the small teeth, called the *peristome teeth,* which extend from the circumference toward the center of the open end of the capsule. With a sharp knife cut off the upper part of the capsule bearing the peristome teeth. Place this on a slide and examine with a hand-lens and with the low power of the mi-

croscope. Make a drawing (5 cms. in diameter) showing the upper end of the capsule with the peristome teeth as seen from above. Make a drawing (3 cms. long) of 3 peristome teeth.

Examine with a hand-lens the spores from a capsule. Make a drawing (1 cm. in diameter) of two spores as seen under the microscope. The spore is the first stage of the *gametophyte* generation. The spores are distributed by the wind. Under favorable conditions a spore germinates, producing the branched, filamentous *protonema,* on which are borne buds which give rise to the erect leafy branches.

Questions: 1. Explain how the gametophyte of the moss differs from that of the liverwort (*Anthoceros*). 2. In obtaining food, how does the sporophyte of the moss differ from that of the *Anthoceros?* 3. Do the stomata of the *Anthoceros* occur in the gametophyte or in the sporophyte? 4. Make a circular diagram to show the life-history of the moss.

D. PTERIDOPHYTA: PTERIDOPHYTES: FERN PLANTS

The *Pteridophyta* resemble the Bryophyta in possessing a female reproductive organ called an *archegonium,* and in passing through two *alternating generations,* gametophyte and sporophyte. The nuclei of the sporophyte generation contain the double number of chromosomes (2x) and those of the gametophyte generation contain the single number (x).

In the Pteridophyta the sporophyte is the highly developed generation composed of true roots, stems, and leaves, containing true tissues, including a fibro-vascular tissue system. The gametophyte is a comparatively undeveloped and inconspicuous structure, called a *prothallium.* The base of the archegonium is embedded in the prothallium. The most striking differences between the Bryophytes and the Pteridophytes are (1) that in the Bryophytes the gametophyte is the more highly developed generation, while in the Pteridophytes the sporophyte is the more highly developed generation; and (2) that the Pteridophyta develop true roots, stems, and leaves, which contain a vascular system, while the Bryophyta do not develop these structures.

The Pteridophyta are divided into three groups: (1) *Filicinae* or Ferns; (2) *Equisetinae* or Horsetails; and (3) *Lycopodinae* or Club-mosses.

1.

Pteridophyta: Fern plants
Filicinae: Ferns
Fern.
a. The gametophyte

Examine the ground beneath ferns growing in a moist ravine. Look for small flat heart-shaped thalli (about 1 cm. across). These are *fern prothallia* (singular *prothallium*). Collect prothal-

lia of different sizes, and take these to the laboratory. Carefully wash in water a young prothallium to remove soil. Place the prothallium on a slide and examine with the hand lens. Describe its shape. How do its upper and lower surfaces differ? What part of the prothallium is the thickest? Does the prothallium contain chlorophyll? Can it absorb water and dissolved mineral substances? Is the fern prothallium (which is the gametophyte) an independent plant? Make an outline drawing (8 cms. long) of the lower surface of the prothallium. Growth takes place by the division and subsequent enlargement of cells at the base of the notch between the two lobes. This part is the *growing point.* The root-like structures are the *rhizoids.*

(1) *Antheridia.* Examine a small prothallium with the hand lens and low power of the microscope for *antheridia.* The antheridia are usually located near the rhizoids. The antheridia may be recognized as small spherical bodies, usually brownish in color, which project slightly above the surface of the prothallium. Indicate the position and size of the antheridia by means of small circles on the drawing you have made.

(2) *Archegonia.* An older prothallium should be examined with the low power of the microscope for *archegonia.* The necks of the archegonia, which appear as short columns of cells, project above the surface of the prothallium, in the region near the notch. The archegonium is flask-shaped with its base sunken in the prothallium. The *egg-cell* (*female gamete*) lies in the sunken base of the archegonium. Show the distribution and size of the archegonia on the diagram already drawn. The archegonia may be represented by V-shaped marks. From prepared sections of the prothallium draw antheridia and archegonia, showing the details of their structure.

The sperm cells, which are provided with *cilia,* are liberated from an antheridium, and move through water to an archegonium. The sperm cells swim down a canal-like opening in the neck of the archegonium. A single sperm cell unites with the egg, producing an oospore, which is the first stage of the sporophyte generation. Fertilization in the fern is thus exactly like that in the moss and in the liverwort. From the oospore the embryo is formed; and from the embryo develops the mature sporophyte, which is the ordinary leafy fern plant.

b. The Sporophyte

(1) *Origin of the spore-bearing plant.* Examine a prothallium which shows a young fern sporophyte growing from it. Is this attached to the upper or to the lower surface of the prothallium? Note that the root grows from the young sporophyte and not from the prothallium. Make a drawing (6 cms. long) showing young sporophyte attached to the gametophyte.

(2) *The spores.* Examine a mature sporophyte, collected from the same place where the prothallia were found. Note that it is composed of the true roots, stems, and leaves. On the lower surface of the leaf find small brown spots, visible to the naked eyes. These spots are groups of *sporangia* (spore-cases), usually covered by a membrane called the *indusium.* The spots are called *sori* (singular sorus). Make a drawing of a leaf showing the distribution of the sori.

Remove the indusium from a sorus and examine the sorus under the microscope. Note the numerous sporangia or spore-cases. Is each sporangium provided with a stalk? Make a drawing showing the sorus covered by the indusium. Make another drawing showing the group of sporangia with the indusium removed.

Examine several sporangia under the low and the high power of the microscope. Note the incomplete ring of thick-walled cells that encloses the sporangium. Changes in water-content of the ring cells cause the sporangium to rupture and the spores to be ejected. Make a drawing (5 cms. long) of a single sporangium. Draw 3 spores under high power of the microscope. The spore is the first stage of the gametophyte generation. By germination and growth the spore produces the prothallium (mature gametophyte).

Questions: 1. How does the gametophyte of the fern differ from the gametophyte of the Bryophytes in structure and in the way it obtains its food? 2. How does the sporophyte of the fern differ from the sporophyte of *Anthoceros* and of the moss? 3. Make a circular diagram to illustrate the complete life-history of the fern.

E. SPERMATOPHYTA: SPERMATOPHYTES: SEED PLANTS

I. INTRODUCTORY

a. General

The *Spermatophyta,* or *seed plants,* include nearly all of the plants of agricultural importance and make up most of the volume of the vegetation covering the earth. Because of its possession of an apparently more clearly observable reproductive method, a seed plant is sometimes called a *Phanerogam* (meaning with *visible marriage*), as opposed to a *Cryptogram* (meaning with *hidden marriage*). On account of complex and often showy floral structures, Spermatophytes are frequently called *flowering plants.* Furthermore, because they exhibit the greatest specialization and complexity of structure, they are often called the *higher plants.* The Spermatophytes have descended from the Pteridophytes. The immediate ancestors of the Spermatophytes are now extinct, but they probably resembled the ferns.

Sporophyte and Gametophyte.[1] An alternation of generations takes place in the Spermatophytes, as in the Archegoniates.

[1] As in the Bryophytes and in the Pteridophytes, the number of chromosomes in the nuclei of the sporophyte generation of Spermatophytes is twice as great as in the nuclei of the gametophyte generation.

But the process is more obscure than in many of the Archegoniates. The Spermatophytes bear spores of two kinds: (1) *microspores* (small spores) which produce *male gametophytes,* and (2) *macrospores* (large spores) which produce *female gametophytes.* The gametophyte generation is limited to one or a few cells within the pollen grain and within the ovule. The macrospore remains enclosed by the *macrosporangium* (the *ovule*) and there it develops into the female gametophyte, containing the egg cell. The *pollen grain* (the *microspore*) germinates, producing a tube which grows to the ovule. This stage, represented by *pollen grain* with the *pollen tube* is the *mature male gametophyte.* Fertilization takes place by the union of a sperm, from the pollen tube, with the egg cell. The *embryo* sporophyte then develops from the fertilized egg. After reaching a certain stage of development, the embryo stops growing and remains in an inactive or resting condition. This structure composed of the resting embryo sporophyte, enclosed by the ovule (macrosporangium), and often by other structures, is the *seed.* The seed is soon released from the parent sporophyte and under favorable conditions germinates and develops into a mature sporophyte plant.

b. Definitions Applying to the Spermatophyta

Higher plant: the sporophyte, composed of highly organized roots, stems, and leaves (2x).[2]

Ovule: macrosporangium of seed plants; part of the sporophyte (2x).

Stamens and pistils: the spore-bearing parts; parts of sporophyte (2x).

Carpel: macrosporophyll, leaf which bears the ovule; part of the sporophyte (2x).

Gynaecium: all of the carpels together; part of the old sporophyte (2x).

Ovary: closed chamber composed of one or more carpels, containing the ovule or ovules; found only in *Angiosperms;* part of sporophyte (2x).

Stigma *Ovary* *Style*	carpel or several united carpels	macrosporophyll; part of sporophyte (2x).

Pollen sac: microsporangium, in which pollen grains (microspores) are produced; the essential part of the anther; part of sporophyte (2x).

Stamen: Microsporophyll; the leaf which bears the microsporangia or pollen sacs (in anthers); a part of the old sporophyte (2x).

[2] The sporophyte and gametophyte generations are indicated by (2X) and (X), respectively.

Androecium: The stamens collectively; part of the old sporophyte (2x).

Pollen grain: microspore of a flowering plant; male gametophyte generation (x).

Germinated pollen grain (with pollen tube): mature prothallium containing sperm nuclei and prothallium nucleus; male gametophyte (x).

Embryo sac: In early stages, the macrospore; in later stages, encloses the mature female gametophyte (x).

Reduction of chromosomes from 2x to x: Occurs in the formation of the pollen grain, and in the formation of the embryo sac.

Fertilization: Fusion of a sperm cell from the pollen tube with the nucleus of the egg cell in the female gametophyte (within the ovule).

Embryo: The young sporophyte produced from the fertilized egg, and present in the seed (2x).

Endosperm: Xeniophyte (3 x generation); one sperm nucleus fused with endosperm nucleus of embryo sac (in Angiosperms).

Seed: A structure developed from the ovule as a result of fertilization, consisting of an embryo, seed coats, and sometimes a food-store outside of the embryo. This is a reproductive structure adapted to dissemination. (2x and 3x.)

c. *Divisions of the Spermatophyta*

The *Spermatophyta,* or seed plants, are divided into two classes. *Class I. Gymnospermae.*[3] (Plants with naked seeds.) Plants of this class are distinguished from other seed plants by the absence of an ovary, the ovules being borne freely exposed on the macrosporophylls or carpels. This is the older of the two groups, being more closely related in its reproduction to the Archegoniates and having the simpler plant body. *Class II. Angiospermae.*[4] (Plants with seeds in a box.) Plants of this class are distinguished from the *Gymnosperms* by having their ovules and seeds enclosed in an ovary, composed of one or more macrosporophylls or carpels. This class is less primitive than the class of Gymnosperms and its plant body is more complex and more highly specialized. Our study of Spermatophytes will be confined to this group, since it includes almost all agricultural crop-plants.

CLASS II. ANGIOSPERMAE

Cotyledon single, vascular bundles scattered—
Sub-class 1. MONOCOTYLEDONES.

Cotyledons two, bundles usually in a ring—
Sub-class 2. DICOTYLEDONES.

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[3] Gymnospermae; from Gr. **gymnos**, naked; **sperma**, seed.
[4] Angiospermae; from Gr. **angion**, a case; **sperma**, seed.

d. Drawings and Notes

In studying the families of *Angiosperms,* make notes in the laboratory of the features which are characteristic of each of the plant families. Make drawings to show these family characteristics. The following list gives the drawings that it may be necessary to make. Usually it will not be necessary to make all of these.

1. The entire plant, or a portion showing root, stem and leaves.
2. Outline of leaf, showing also attachment to stem.
3. Flower, to show general form (from the side or from the top).
4. Flower cut longitudinally, as seen from the side; or a longitudinal diagram of the flower.
5. Floral diagram, as seen in cross-section.
6. Petals.
7. Sepals.
8. Stamen, showing dehiscence.
9. Pistil, showing form of parts.
10. Cross and longitudinal sections of the ovary, showing cells and placentation.
11. Ovule, enlarged.
12. Fruit, from the side, and in cross-section if necessary.
13. Seed, showing attachment to fruit.
14. Seed, in section.

e. Economic Value

Under each family make a list of the plants useful to man. Give the name and kind of the useful product. State also the part of the plant which is used, whether root, stem, leaf, flower, or fruit. Discuss the place and manner of cultivation, and value of the products.

1. *Foods.* Beverages: non-alcoholic, alcoholic. Starch. Sugar: sucrose, glucose. Vegetables. Nuts. Fruits. Oils. Spices and flavorings. Other foods.
2. *Clothing.* Fibers. Other materials for clothing.
3. *Building materials.* Soft woods. Cabinet woods. Other building materials.
4. *Fuel.* Firewood, charcoal, alcohol, oils.
5. *Rubbers, gums, resins.*
6. *Drugs and poisons.*
7. *Tans and dyes.*
8. *Fibers. Rope. Cord. String. Bags. Carpets.*
9. *Perfumes.*
10. *Feed for live stock.* Forage plants, etc.

A. SUB-CLASS I. MONOCOTYLEDONES

In the *Monocotyledones* the embryo possesses a single cotyledon, which frequently has the function of absorbing food that is stored in the endosperm (*xeniophyte*) of the seed. The roots are usually very slender, the primary root being succeeded by many slender roots of high tensile strength growing from the base of the stem. The stems are commonly slender and remain of nearly the same thickness throughout the life of the individual. The outer part of the stem is generally tough and the inner part soft or hollow. The fibro-vascular bundles are scattered irregularly throughout the parenchyma. Thus the stem has no distinct layers of bark and wood, with a layer of cambium separating the two. The bundles are *closed,* since they contain no cambium; hence increase in diameter of the stem usually does not take place. The leaves are commonly parallel-veined, with entire margins. The parts of the flower are usually in whorls of 3 or 6, never 5, as in the *Dicotyledones*. The *Monocotyledones* include the most important agricultural plants in the Philippines; among these are rice, coconut, abacá, maize, and sugar cane.

(A). Series A. The Primitive Monocotyledones

(1). Gramineae (grass or zacate family)

Annual or perennial plants, usually herbaceous, but in the bamboos, woody and tree-like. Stems cylindrical, jointed; usually hollow (except at the joints), with swollen joints. Leaves alternate, simple, usually long, slender, parallel-veined, with a basal sheath slit down one side. Flowers lacking a perianth, but protected by scaly bracts (*glumes*). Stamens usually 3 (sometimes 1 to 6). Ovary superior (placed above the other floral parts), one-celled, one-ovuled. Fruit a one-seeded, superior fruit, with the wall of the ovary united with the seed (a *caryopsis*). Seeds always contain food stored in the endosperm, with the embryo lying in contact with it at one side. Cotyledon (*scutellum*) absorbs food used in the growth of the seedling.

Review the work which you have already done upon *Oryza sativa,* rice, and then make drawings to show the essential features of the following:

Saccharum officinarum, Sugar cane, Tuba. *Zea mays,* Maize, Corn. *Bambusa blumeana* (*spinosa*), Bamboo, Cauayan, Cauayan totoo, Spiny Bamboo. *Bambusa vulgaris,* Canayan quiling. *Imperata cylindrica, var. koenigii,* Cogon.

(2). Palmae (palm or anahao family)

Erect woody shrubs or trees, slender, sometimes very tall. Mostly tropical and subtropical. Stems typically unbranched, cylindrical, of uniform diameter throughout. Roots thin, very nu-

merous. Leaves alternate, forming a crown at the tip of the stem, usually very large, pinnately or palmately divided, with sheathing bases. Bases of leaves often attached to the trunk, or by falling away leaving prominent leaf-scars on the stem. Flowers, small, borne on a thick, swollen, often much-branched stalk, called a *spadix,* that is often enclosed when young in a large sheath called a *spathe,* which bursts before the flower cluster expands. Perianth with 3 sepals and 3 petals, usually all free (not united with each other), usually green or yellowish in color. Stamens 3 to 6, sometimes more. Ovary one to 3-celled, or of 3 one-celled carpels, superior (above the other floral parts); stigmas 3, usually sessile (style absent); ovule usually one or two in each carpel. Fruit a 1 to 3-seeded drupe (with outer part soft, the inner hard), or nut-like (a hard one-seeded fruit, not opening at maturity), or berry-like (soft throughout), with 1 to 3 carpels.

Cocos nucifera, Niog, Coco, Coconut. *Corypha elata,* Buri, Buli. *Areca catechu,* Bunga, Betel-nut Palm. *Nipa fruticans,* Nipa, Sasa. *Arenga saccharifera,* Caong, Iroc, Cabo negro, Sugar palm. *Oreodoxa regia,* Royal Palm. *Calamus mollis,* Uay, Bejuco, Rattan. *Normanbya merrillii,* Bunga de China, Bunga de Jolo.

(3). Araceae (arum or gabi family)

Generally perennial herbs that have their aerial parts coming from thickened underground stems (rhizomes, corms, or tubers). Many have a milky juice. Some of the members of this family are woody vines, climbing by roots; and one genus includes water plants. Leaves alternate, often heart-shaped with netted venation, or in some cases long with parallel venation. Flowers small, sessile on a thick, fleshy, unbranched stalk (*spadix*), protected by a large, often brightly colored bract called a *spathe.* Perianth none, or of 4 to 6 sepal-like parts. One stamen usually opposite each perianth segment; anthers 2 to 4-celled. Ovary sessile, one to three-celled; ovules one or more. Fruit berry-like, one to many-seeded.

Colocasia esculentum, Gabi, Taro, Dasheen. *Amorphophallus campanulatus.* Pungapung. *Xanthosoma sagittifolia,* Yautia, Dasheen. *Raphidophora merrillii,* Tibatib, Amlong. *Caladium bicolor,* Corazon de Maria. *Alocasia indica,* Biga, Elephant's Ear.

(*B*). *Series B. The differentiated Monocotyledones*

(4). Dioscoreaceae (yam or ubi family)

Usually perennial, twining herbaceous vines, with large fleshy roots or rhizomes. Leaves stalked, simple, often heart-shaped, or composed of 3 to 7 leaflets arising at the apex of the petiole; frequently netted-veined. Flowers small, regular, greenish in color, staminate (with stamens but no pistil) or pistillate (with pistil but no stamens). Staminate flowers with a 6-lobed pe-

rianth; stamens inserted at the base of the perianth or on its lobes, 3 or 6, or sometimes 3 perfect and 3 staminodes (imperfectly developed stamens). An imperfectly developed ovary may be present in the staminate flowers. Pistillate flowers similar to the staminate ones; staminodes 0, 3, or 6; ovary 3-winged, 3-celled; ovules 2 in each cell. Fruit a capsule (a dry dehiscent seed-vessel), 3-winged, opening by 3 valves. Seeds winged.

Dioscorea alata, Ubi, Yam. *Dioscorea fasciculata,* Tungo, Tugue, Tamis. *Dioscorea daemona,* Nami, Corot.

(*C*). *Series C. The Specialized Monocotyledones*

(5). Musaceae (banana or saguing family)

Herbs with erect trunks, tree-like or palm-like in appearance, with leaves all at the apex. The trunk is frequently composed of overlapping leaf bases, the true stem appearing only a short time before flowering. Leaves very large, oblong. Flowers very irregular, usually with bracts. Petals free or united with each other, the corolla often swollen and surrounding the anthers and style. Stamens 5, separate; staminode one or none. Ovary inferior (below the other flower parts, which grow from the summit of the ovary), 3-celled; ovules one to many in each cell. Fruit a berry (soft and fleshy) or a capsule (a dry fruit, opening at maturity). Seeds with *perisperm* (nutritive tissue of the nucellus which persists in the seed).

Musa textilis, Abacá, Manila Hemp. *Musa sapientum,* Saguing, Banana. *Musa paradisiaca,* Saguing, Plantano, Plantain.

B. SUB-CLASS II. DICOTYLEDONES

The embryo of the *Dicotyledones* possesses two opposite cotyledons; these frequently serve as food storage organs in the seed and later often serve as photosynthetic organs; sometimes they act as food absorbing organs. The roots usually increase in diameter as the plant grows older; the root system is commonly composed of the primary root and branches from it. The stem is composed of distinct zones of bark, wood, and pith. The fibrovascular bundles in the stem are usually arranged *in a ring* around the central pith. The bundles are *open* and contain a layer of *cambium* separating the xylem and the phloem. This cambium layer forms a complete cylinder separating the bark from the inner woody tissues of the stem. In herbaceous plants the wood is less distinct than in the woody plants. As a result of the activity of the cambium, the stem exhibits a gradual increase in diameter (secondary growth in thickness) as the plant grows older. The leaves are nearly always netted-veined and exhibit great variation in shape. The parts of the flower are usually in whorls of 5 or sometimes 4, but not 3 or 6, as in the *Monocotyledones*.

(A). Series A. The Primitive Dicotyledones

(1). Moraceae (mulberry, Fig, or balite family)

Shrubs or trees, sometimes vines, usually with abundant milky sap, rarely herbaceous. Leaves alternate or opposite, simple, often toothed or lobed, the stipules falling early. Flowers inconspicuous, staminate or pistillate, both kinds often occurring on the same plant, mostly wind pollinated, densely crowded on the outside of variously shaped receptacles or covering the inside of a closed receptacle. Staminate flowers with 4 (sometimes 2 to 6) perianth segments; calyx and corolla not distinct; stamens usually as many as the segments and opposite them, sometimes only 1. Pistillate flowers with usually 4 segments. Ovary one-celled (or rarely 2-celled); styles and stigmas 2 (sometimes only one); one ovule in each cell, pendulous, curved. Fruit composed of many more or less united carpels, each surrounded by its enlarged, fleshy perianth; rarely dry, sometimes (*Ficus*) the individual fruits are borne on the inside of a fleshy, closed, receptacle. Seeds usually contain endosperm.

Artocarpus integrifolia, Lanca, Nanca, Jak-fruit. *Artocarpus communis,* Rimas, Camansi, Bread-fruit. *Ficus elastica,* India Rubber Tree. *Castilloa elastica,* Castilloa Rubber Tree. *Morus alba,* Moral, Morera, Mulberry.

(B). Series B. The Differentiated Dicotyledones

(2). Anonaceae (custard apple or lanutan family)

Trees or shrubs, sometimes vines. Leaves alternate, without stipules, simple, entire. Flowers often large, perfect (with both stamens and pistil in the same flowers). Green calyx composed of 3 sepals. Colored corolla made up of 6 petals, distinct and separate, inserted below the ovary, in two whorls, or the inner whorl absent. Stamens many, inserted below the ovary; filaments short or absent; anthers united, the portion between the pollen-sacs developed into a head. Ovary one or more, free or united, superior; stigmas distinct; style none or very short; ovule one or more. Fruit of one or more, one to many-seeded, fleshy, indehiscent, berry-like carpels, rarely dry and dehiscent.

Anona muricata, Guanabanos, Guyabano, Soursop. *Anona reticulata,* Anonas, Custard Apple. *Anona squamosa,* Ates, Atis, Sugar Apple, Sweetsop. *Canangium odoratum,* Ilang-ilang.

(3). Cruciferae (mustard or mostaza family)

Herbs with watery, often pungent and irritating juice. Basal leaves in a whorl, those on the stem alternate, simple, entire or lobed. Flowers regular, arranged singly along a common flower-stalk, which is usually without bracts. Sepals 4, free, the two lateral ones often large and bag-shaped at the base. Petals 4,

free, usually narrow, opening at an angle of 90° from each other, resembling a cross (hence the name *Cruciferae*). Stamens usually 6, the two outer short, and opposite the lateral sepals, the 4 inner longer, in opposite pairs. Receptacle usually with 4 glands opposite the sepals. Ovary 2- or one-celled, free from the calyx; styles short or none; ovules usually many, in 2 series, curved. Fruit usually a 2-celled, 2-valved dry pod, the valves separating from the base upward and leaving the seeds on a dividing membrane, or indehiscent, or jointed. Seeds small; the embryo curved.

Raphanus sativus, Rabanus, Labanus, Rabano, Radish. *Brassica oleracea,* Cabbage. *Brassica pekinensis,* Skeels, Pechay. *Brassica juncea,* Moztaza, Mustard.

(4). Leguminosae (bean or narra family)

Herbs, shrubs, vines, or trees. Leaves usually alternate, with stipules, simple, digitate or pinnate. Flower clusters various. Flowers regular (*Mimosoideae*) or irregular, usually perfect (with both stamens and pistil in a single flower). Calyx usually toothed or lobed. Petals usually 5, sometimes only one or 3, alike (*Mimosoideae*) or very different. Stamens typically 10, fewer in some genera, or very numerous in some *Mimosoideae;* filaments free or united. Ovary free, composed of one carpel, one-celled, superior (placed above the other parts); one to many ovules in this single cell. Style simple; stigma globular, terminal, or oblique. Fruit a usually dry or sometimes fleshy pod or *legume,* composed of one carpel, usually splitting down two seams, or sometimes indehiscent, or separating into one-seeded, indehiscent joints. Seeds usually without endosperm. Three subfamilies are distinguished.

1. Petals in the bud meeting without overlapping; flowers regular .... *A. Mimosoideae.*

1. Petals overlapping in the bud; flowers irregular.

   2. Flowers *not papilionaceous* (butterfly-shaped); the upper petal interior .... *B. Caesalpinioideae.*
   2. Flowers *papilionaceous,* the upper petal (standard) exterior .... *C. Papilionatae.*

A. Mimosoideae.

Leucaena glauca, Ipil-ipil, Malaganit. Enterolobium (*Samanea*) *saman,* Acacia, Rain-tree. *Acacia farnesiana,* Aroma. *Albizzia procera,* Acleng-parang, Aninapla. *A. acle,* Acle. *Mimosa pudica,* Macahia, Sensitive Plant.

B. Caesalpinioideae.

Caesalpinia pulcherrima, Caballero. *Tamarindus indica,* Sampaloc, Tamarindo, Tamarind. *Intsia bijuga,* Ipil. *Pahudia rhomboidea,* Tindalo.

C. Papilionatae.

Arachis hypogaea, Mani, Peanut. *Pterocarpus indicus,* Narra, Naga. *Pisum sativum,* Pea, Chicharo. *Sesbania grandiflora,* Caturay, Gauay-gauay. *Erythrina indica,* Dap-dap. *Phaseolus lunatus,* Patani, Lima bean. *P. vulgaris,* Habichuela, Common bean. *P. radiatus,* Mungos, Green Gram. *Vigna sinensis,* Cowpea. *V. sesquipedalis,* Sitao. *Gliricidia sepium,* Madre cacao, Cacauate. *Pachyrrhizus erosus,* Sincamas. *Cajanus cajan,* Caguios. *Psophocarpus tetragonolobus,* Calamismis, Winged-bean. *Glycine max,* Soy bean, Soja.

(5). Rutaceae (orange or lucban family)

Shrubs or small trees, sometimes vines, often spiny. Leaves glandular with translucent dots (oil-glands), alternate (or rarely opposite), simple or pinnate. Flowers regular, perfect, variously arranged on the flower stalks. Calyx 4- or 5-toothed. Petals 4 or 5, or more, free. Stamens 4 to 10, or in some genera numerous; filaments inserted below the ovary, free or united into a tube. Ovary superior, of 4 or 5, free or united carpels, or simple and many celled, free from the calyx; styles free or united. Ovules one or 2 to many in each cell. Fruit a fleshy berry or drupe, or a capsule, or of one to 4 separate carpels.

Citrus mitis. Calamansi, Calamondin. *C. decumana.* Lucban, Pomelo. *C. lima.* Dayap, Limon. *C. maxima,* Pomelo. *C. nobilis.* Satsuma orange. *C. medica.* Citron.

(6). Euphorbiaceae (euphorbia or lumbang family)

Herbs, shrubs, trees, rarely vines, frequently with milky juice. Leaves alternate or opposite, entire or variously toothed or lobed; rarely compound (*Bischofia*), or absent. A number of the plants in this family contain poisonous substances; the roots of *manihot,* for example, contain prussic acid, which may be removed by washing, cooking, or drying in the sun. Flower clusters various. Flowers mostly small, always either staminate or pistillate, monoecious (pistillate and staminate flowers on the same plant) or dioecious (pistillate and staminate on separate plants). Perianth simple, calyx-like, often wanting in pistillate or staminate flowers, or both. Perianth sometimes with the inner whorl of 4 or 5 small petals, or in *Euphorbia* entirely wanting, the solitary pistil surrounded by few to many stamens, all enclosed in a perianth-like set of bracts. Stamens few to many, the filaments free or united. Ovary superior, usually 3-celled; usually of 3 united carpels; styles as many as the carpels, free or united; ovules one or 2 in each cell, pendulous, with an upwardly and outwardly turned micropyle. Fruit a capsule composed of 2-valved, one or 2-seeded carpels, separating from a central axis; drupe-like, nut-like, or berry-like. Endosperm well-developed.

Manihot utilissima, Camoteng-cahoy, Manioc, Cassava, Tapioca plant. *Ricinus communis,* Tangan-tangan, Castor-oil Plant, Castor Bean. *Hevea brasiliensis,* Para Rubber Tree.

(7). Anacardiaceae (cashew or mango family)

Trees or shrubs, often with acrid and sometimes milky juice. Leaves alternate, without stipules, simple or pinnate. Inflorescence commonly irregularly branched. Flowers small, regular, staminate or pistillate, perfect, or polygamous (some perfect and some staminate or pistillate flowers on the same plant.) Calyx composed of 3 to 6 parts. Petals 3 to 6, alternate with the sepals, free. The receptacle expanded, cup or ring-shaped, entire or lobed. Stamens as many as or twice as many as the petals, rarely fewer or only one; inserted under, rarely on, the expanded receptacle. Filaments usually tapering to a sharp point; anthers 2-celled. Ovary superior, one to 5-celled, or in *Buchanania* of 5 or 6 free carpels, often poorly developed in the staminate flowers; styles one to 6; one ovule in each cell. Fruit a one to 5-celled, one to 5-seeded drupe.

Mangifera indica, Manga, Mango. *Anacardium occidentale,* Casoy, Cashew. *Spondias purpurea,* Sirihuelas. *Semecarpus cuneiformis,* Ligas. (With poisonous leaves.)

(8). Malvaceae (hibiscus or gomamela family)

Herbs, shrubs, or trees, rarely vines. Leaves simple, alternate, usually lobed, and with the herbaceous parts often covered with star-shaped hairs; stipules free, sometimes falling early. Small bracts 3 or more, whorled at the base of the calyx, or wanting. Flowers axillary or terminal, regular, perfect. Sepals 5, free or united. Petals 5, separate, or united at the base, twisted in the bud. Stamens many, rarely few, the filaments united into a tube which is more or less united with the base of the petals; anthers various. Ovary 2- to many-celled, of 2 or more carpels arranged in a whorl around a central axis, free from the calyx. Fruit composed of dry carpels, separating from the axis, or capsular and loculicidal (capsules opening by splitting through the back of each cell).

Hibiscus sabdariffa, Rozelle. H. schizopetalus, Gomamela, Araña. *H. rosa-sinensis,* Gomamela, Araña. *Abelmoschus esculentus,* Okra, Gumbo. *Gossypium hirsutum,* Bulac, Algodon, Cotton.

(9). Sterculiaceae (cacao or calumpang family)

Herbs, shrubs, or trees, usually hairy. Leaves alternate, simple, or with leaflets borne at the apex of the petiole, often lobed, with stipules. Inflorescence various. Flowers regular, perfect, or pistillate, or staminate. Sepals 5, more or less united. Petals 5 or none. Stamens 10 or numerous, united at the base into a

short tube, rarely few and free; anthers variously arranged on the staminal-tube. Ovary free, 2- to 5-celled, rarely of one carpel, sessile or stalked; styles united; ovules always more than one in each cell, attached to the inner angles of the carpels. Fruit dry or fleshy, dehiscent or indehiscent, often a capsule.

Theobroma cacao. Cacao, Chocolate Tree. *Sterculia foetida.* Calumpang, Bangar, Bobog. *Kleinhofia hospita.* Tanag, Bitnong. *Melochia arborea.* Labayo. *Heritiera littoralis.* Dungon-late.

(10). Dipterocarpaceae (dipterocarp or lauan family)

Trees, usually of large size, with tall trunks, often unbranched to a considerable height. Leaves evergreen, simple, alternate, with stipules, pinnately-veined (the veins running parallel near the margin); stipules often small and falling off early. Wood, pith, bark, and leaves usually containing resin. Fruits with sepals prolonged into wings, which usually exceed the fruit in length and aid in its dispersal. (Name of family refers to *winged fruits.*) Flowers perfect, numerous, in irregularly-branched flower clusters, usually with parts in groups of 5. Receptacle conical and attached at the narrower end, sometimes concave. Stamens many, 15, 10 or 5. Carpels 3 to one with each of the two anatropous (inverted) ovules with two seed coats. Style short or long, smooth, its base often enlarged. Stamens of various forms; filaments often united; anthers with portion between pollen sacs often prolonged. Only one of the ovules develops into a perfect seed. Cotyledons with long petioles; radicle superior; hypocotyl often as long as the embryo. Cotyledons usually two-parted at the base and often divided into numerous lobes. Seeds often with endosperm.

Parashorea plicata, Bagtican Lauan. *Shorea guiso, Guiho. Pentacme contorta,* White Lauan.

(C). *Series C. The Specialized Dicotyledones*

(11). Sapotaceae (guttapercha or chico family)

Trees or shrubs with milky juice, the young parts often with rust-colored, silky hairs. Leaves alternate, entire, petioled. Flowers perfect, regular. Calyx-lobes 4 to 8, in one or two whorls. Corolla-tube short, the lobes as many as, or 2 to 4 times as many as, the calyx-lobes. Stamens inserted on the corolla-tube, as many as the lobes and opposite them, or 2 or 3 times as many and in several rows; staminodes (imperfect stamens) often present, alternating with the stamens. Anthers extrorse (with their pores facing outward). Ovary superior, sessile, 2- to 12-celled. Usually one erect ovule in each cell. Fruit a berry. Seeds usually few, one in each cell, rather large, with bony, shiny brown testa and a large lateral hilum.

Achras sapota, Chico. *Palaquium sp,* Guttapercha. *Mimusops elengi,* Bansalaguin.

(12). Ebenaceae (ebony or camagon family)

Trees or shrubs without milky sap. Leaves alternate, entire, usually leathery, without stipules. Flowers usually with a leathery perianth, dioecious, (that is, staminate flowers on one individual, pistillate flowers on another), variously arranged in clusters, the individual flower-stalks jointed under the flowers. Flower parts in groups of 3 to 5. Calyx-lobes united below, often enlarged in the fruit. Corolla-tube cylindrical, usually hairy outside. Stamens as many as the corolla-lobes, or 2 or 3 times as many, hypogynous, free or the filaments united, the pistillate flowers with or without stamen-like staminodes. Ovary superior, free, sessile, 3- to 10-celled; styles one to 8; ovules one or 2, pendulous, in each cell. Fruit a berry or leathery in texture, globose or ovoid, indehiscent, few- or several-seeded.

Diospyros discolor, Mabolo, Camagon.

(13). Convolvulaceae (morning glory or camote family)

Slender, spreading or prostrate herbs, or twining herbaceous or woody vines, sometimes with milky juice. Leaves, alternate, simple, without stipules. Flowers regular, perfect, often large and showy. Sepals 5, usually persistent, almost free, often growing larger after flowering. Corolla bell-shaped, salver-shaped, urn-shaped, rarely wheel-shaped, the edge of the corolla with 5 lobes, often folded lengthwise and twisted to the right in the bud. Stamens 5, attached to the corolla-tube. Ovary superior, of 2 usually united carpels, often surrounded by a ring-shaped or lobed, expanded receptacle; ovules 2 in each cell; one style, with two lobes; rarely 2 styles. Fruit an indehiscent, often dry berry, or a 2- to 4-valved capsule; usually nearly spherical. Seeds 2 or 4.

Ipomoea batatas, Camote, Sweet Potato. *Ipomoea nil, Ipomoea purpurea,* Aurora, Morning glory. *Calonyction aculeatum,* Moon Flower. *Quamoclit phoenicea,* Pula.

(14). Solanaceae (talong or night shade family)

Herbs or shrubs, sometimes vines, leaves alternate, simple or pinnate, sometimes in unequal pairs (a large leaf and a small one together), never opposite, without stipules. Many of the plants of this family contain poisonous substances, some of which are valuable drugs. Among such poisons are atropine, belladonna, hyocyamus, and nicotine. Inflorescence various. Flowers perfect, regular or nearly so. Calyx inferior (placed below the other flower parts), usually persistent and often enlarged in the fruit. Corolla various, petals united, often folded lengthwise, the lobes 5. Stamens 5 (4 in 2 pairs in *Brunfelsia*), inserted on the corolla-tube. Ovary 2-celled or imperfectly one- to 4-celled; ovules numerous on a very thick axile placenta. Fruit a berry or capsule, usually 2-celled, many seeded. Seeds usually kidney-shaped, with a curved embryo in an endosperm.

Nicotiana tabacum, Tabaco, Tobacco. *Solanum melongena,* Talong, Berenjena, Egg Plant. *Solanum toberosom,* Potato. *Lycopersicum esculentum,* Tamate, Camate, Tomato. *Capsicum frutescens,* Pasites, Sili, Chile Pepper. *C. annuum, var. grossum,* Sileng-bilog, Green Pepper.

(15). Rubiaceae (Coffee family)

Herbs, shrubs, or trees, sometimes vines, occasionally spiny. Leaves simple, entire, opposite, with interpetiolar stipules. Inflorescence various. Flowers regular, perfect, or staminate or pistillate. Calyx-tube united with the ovary. Corolla regular, the petals united, usually 4- or 5-lobed, the tube long or short. Stamens as many as the corolla-lobes, inserted within the corolla tube or in its mouth. Ovary inferior (placed below the other parts), usually 2-celled, rarely one celled; style simple or cleft; ovule one or more in each cell. Fruit usually 2-celled, berry-like, capsular, or drupaceous, or of separate carpels. Seeds various.

Coffea arabica, Coffee. *C. excelsa,* Coffee. *C. robusta,* Coffee. *Nauclea media,* Bancal. *Gardenia florida,* Rosal.

(16). Cucurbitaceae (gourd or calabaza family)

Tendril-bearing vines with alternate, simple, lobed or divided, usually heart-shaped leaves. Flowers regular, monoecious, (staminate and pistillate flowers on the same vine), or dioecious (staminate and pistillate flowers on different vines), variously clustered, usually yellow or white. Calyx-tube united with the ovary, the upper part tubular or bell-shaped, 5-lobed. Petals 5, usually united or sometimes free. Stamens usually 3, sometimes 5 or 2, usually all united, or united in pairs; anthers free or united, the cells straight or folded together lengthwise. Ovary inferior (placed below the calyx and corolla), 3-celled; styles one to 4, usually one with 3 stigmas; ovules many on parietal placenta. Fruit usually a many-seeded berry; sometimes small to very large, fleshy or finally dry, indehiscent or dehiscing by valves or a lid. Seeds numerous, usually imbedded in pulp or fiber, often compressed, frequently wrinkled.

Cucurbita maxima, Calabaza, Squash. *Luffa cylindrica,* Patola, Taboboc. *Luffa acutangula,* Patola. *Momordica charantia,* Ampalaya, Amargoso, Gourd. *Cucumis melo,* Melón, Melon.*Cucumis sativus,* Pepino, Cucumber. *Lagenaria leucantha,* Upo, Opo. *Citrullus vulgaris,* Pacuan, Sandia, Watermelon.

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